
I STILL HAVE
ALL MY FINGERS
DAN
POLLINO
HOW TO BUILD A BIG
SUGAR ROCKET ON A
BUDGET WITHOUT
LOSING A LIMB

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I STILL HAVE ALL MY FINGERS

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HOW TO BUILD A BIG SUGAR ROCKET ON A BUDGET WITHOUT LOSING A LIMB

DAN POLLINO

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"When we try something that nobody has ever done, when we are in front of a blank page and we have to invent everything from scratch, it's obvious that we are facing the risk of failing. But I deeply believe that the worst thing in life is not to fail, it's to never try"

Bertrand Piccard
President & founder, Solar Impulse Project

"Research is what I'm doing when I don't know what I'm doing"

Wernher von Braun
NASA 1960-1972

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CONTENTS

Be Safe		ix
Disclaimer		ix
About the Rocket		x
About the Fuel		xi
About the Parts		xii
How to Use this Book		xiii
Tools you'll Need		xv
1	Making the Rocket Body	1
2	Making the Fins	23
3	Making the Nosecone	45
4	Making the Apogee Detector Part 1	71
5	Making the Apogee Detector Part 2	121
6	Making the Parachute Piston	169
7	Parachute and Parachute Rigging	217
8	Assembling the Upper Body Section	249
9	Making the Nozzle and Engine Casing	269
10	Making the Engine Igniter	303
11	Mixing and Casting the Fuel	329
12	Installing the igniter, smoke element and end cap	361
13	Assembling the upper and lower body sections	385

The following chapters are available online at www.inverseengineering.com

- Making the Launch Rail
- Making the Ignition Controller
- Getting Ready to Launch the Rocket
- Launching the Rocket
- Launching the Rocket Again
- Resources

BE SAFE

Look, you've only got two eyes and ten fingers and if you're like me, you're probably pretty fond of all of them. Every effort has been made to make this rocket project as safe and user friendly as possible. The fuel is so safe you can cut it, drill it or beat it with a hammer and nothing will happen but the potential for an accident is always there. So please, follow the recommendations for personal protective equipment when a step calls for them and use common sense when it comes to safety. Safety is and should always be your primary concern when mixing and using low explosives. The rocket in this book will gain speeds over 400 mph and travel over a mile straight up. It must be launched in a remote, unpopulated area where the possibility of damage or injury is at an absolute minimum.



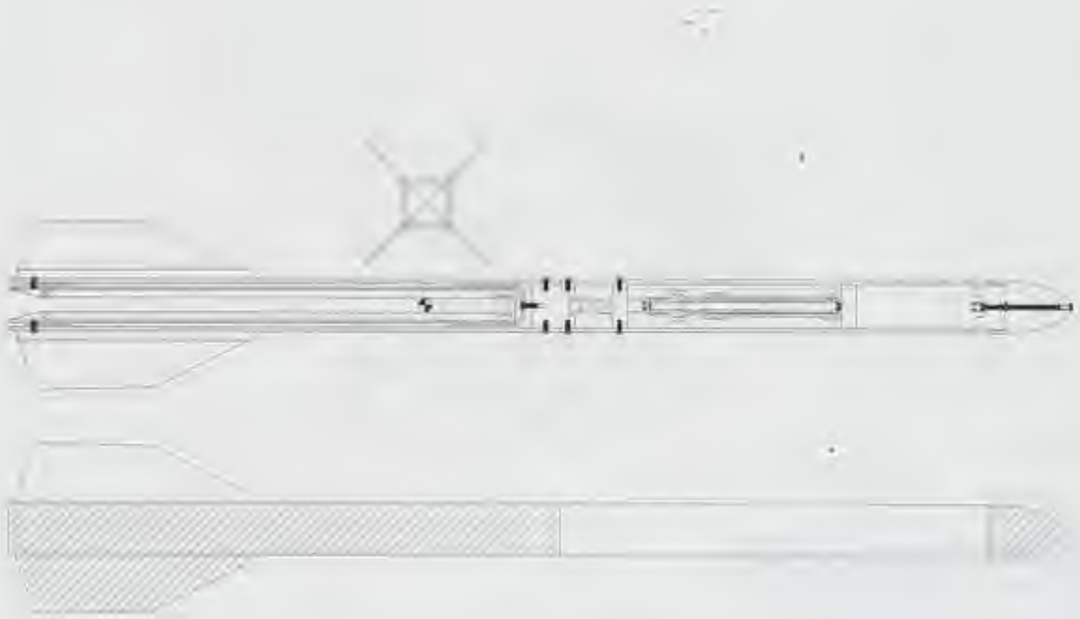
DISCLAIMER

Since 9/11, many additional government restrictions have been added to the manufacture and use of low explosives. Especially those containing potassium nitrate composite mixtures as detailed in this book. A link to federal explosives law has been added to the *Resources* chapter at www.inverseengineering.com to assist you with the proper forms and procedures needed to make and use the rocket legally. Since these rules and regulations are constantly changing, I urge you to research this topic thoroughly on your own. Check with the authorities in your area regarding local testing and launching restrictions.

By purchasing and using this book, I hereby fully and forever release and discharge indemnity and hold harmless the author and Inverse Engineering from any and all liabilities, claims, demands, damages, rights of action, suits or causes of action present of future, whether they be known or unknown, anticipated or unanticipated, resulting from or arising out of my use or intended use of this book. By purchasing and using this book I therefore assume all risk associated with using the rocket described in this book, even if they arise from the negligence of the author or Inverse Engineering. My participation in this activity is voluntary and no one is forcing me to participate in spite of the risks. I understand the effect of this waiver and acceptance of risk on my legal rights.

ABOUT THE ROCKET

I specifically designed the rocket in this book to be a high power, high performance rocket that would be easy to build with common materials and common tools without the need for a machine shop or exotic, dangerous chemicals. The cost is low, compared to commercially available kits with similar performance, which gives it the advantage of being something you can modify and experiment on without breaking the bank. But just because it's inexpensive doesn't mean it lacks performance. The rocket stands 72 inches tall and 3 inches in diameter. Fully fueled it weighs 22 pounds. Once it takes off, it accelerates to over 400 miles per hour in 3 seconds and travels to a maximum altitude of 6000 feet. Not too bad for something you build in your garage out of drain pipe!



ABOUT THE FUEL

The fuel in the rocket engine is made from three major ingredients, powdered sugar, corn syrup and potassium nitrate. The fuel is mixed together and heated in an electric wok to lower the viscosity of the mix so it can be poured into a PVC engine casing. Once the fuel has been poured, it hardens in a few hours and is then ready to use. Making the fuel is surprisingly simple and will work well consistently as long as the measurements and instructions in this book are followed carefully.

Powdered sugar, also known as confectioner's sugar or icing sugar is used in food production where a quick dissolving sugar is required. It is the main fuel component in the K500 fuel mixture and can be found at most food stores.

Corn syrup is made from corn starch and composed mainly of glucose. It is used to soften texture, add volume, prohibit crystallization and enhance flavor in foods. Corn Syrup is used in the K500 engine as a minor fuel and as an element that adds flexibility to the fuel. It can be found at most food stores.

Potassium nitrate, Kno3, is the oxidizing component in the K500 fuel mixture. It is a white powder that has a wide variety of commercial and industrial applications. It can be purchased at any local chemical supplier or online, see the *Resources* chapter at www.inverseengineering.com

The *K* in K500 is a measurement of the total impulse of the engine and the *500* is a measurement of the average thrust. Average thrust is a measure of how slowly or quickly the motor delivers its total energy, and is measured in Newtons. Total impulse is a measurement of the overall energy contained in a rocket motor and is measured in Newton seconds. The letter "K" designation means that there is anywhere from 1,280 to 2,560 Newton seconds of total impulse available in the engine. The K500 has an average thrust of 511 Newtons and a total impulse of 2,273 Newton seconds.

Engine Casing		
Casing Starting Length	35.00	Inches
Casing Ending Length	31.75	Inches
Casing Weight	2.65	Pounds
Total Engine Weight	8.30	Pounds
Grain Geometry		
Grain Length	30.5	Inches
Grain Diameter	2.00	Inches
Core Diameter	1.00	Inches
Nozzle Geometry		
Throat Diameter	0.91	Inches
Throat Area	0.65	Sq. In.
Nozzle Exit Diameter	2.00	Inches
Nozzle Exit Area	3.14	Sq. In.
Expansion Ratio	4.80	
Pressure Ratio	21.8	
Divergent Nozzle Angle	15.0	Degrees

Fuel Composition		
Cubic Inches of Fuel	71.83	Cu. In.
Dry Fuel Weight	5.24	Pounds
Kno3	3.41	Pounds
Corn Syrup	0.89	Pounds
Powdered Sugar	0.94	Pounds
Fuel Weight	4.83	Pounds
Performance Data		
KN	295	
Total Newton Seconds	2273	
Average Thrust in Newtons	511	Newtons
Maximum Thrust in Pounds	280	Pounds
Maximum Chamber Pressure	321	PSI
Engine Rating	K500	
Engine Rating Percentage	88.79	
Thrust Coefficient	1.34	

ABOUT THE PARTS

Many of the parts used to make the rocket are available locally from home supply warehouses like Home Depot, Lowes or other hardware stores. If the rocket is to be constructed exactly as described in this book, some parts will have to be purchased online. The major supplier for online parts used in this book is McMaster-Carr. McMaster-Carr is an industrial supplier based in Los Angeles, Atlanta, Chicago, Cleveland and New Jersey. They can be found online at www.mcmaster.com.

Each step in the book has a list of materials needed to complete that step. Many of these part numbers will be listed as McMaster part numbers. While some of these parts may be available locally, the part numbers are there to ensure the project can be completed exactly as described no matter where you live. I use McMaster as a supplier based on their ability to provide an international reader base with identical parts to the ones used in this book. You may find these parts locally or online for a better price.

A complete list containing part number and prices can be found in the *Resources* chapter at www.inverseengineering.com. The list is categorized by rocket section so if you only want to build the engine and the nosecone, you can see what parts are required and how much each section of the rocket will cost.

Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost. Of course you can always use the extras to build more rockets!

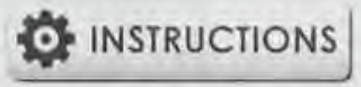


www.mcmaster.com

HOW TO USE THIS BOOK

Each chapter in this book describes the construction of an individual section or part of the rocket. This is good because if you're only interested in making the engine you can skip right to that chapter. However, if you want to build the entire rocket, it's best to follow the chapters in sequential order as they've been laid out to make construction as simple as possible.

Each step in the construction process contains a picture illustrating that step as well as several icon headers that will appear when necessary or relevant.



Below the *Instructions* icon, you will find smaller icons that warn you about any hazards associated with that step or personal protective equipment you should be using during that step to protect yourself.



Ear protection is required.



Eye protection is required.



Gloves are required.



Respirator is required.



Hand laceration hazard.



Material is flammable.



Material is explosive.

MATERIALS

The materials icon lists all the materials required in that particular step.

OPTIONS

The options icon lists any alternative materials or methods that can be used to save time or money.

PRINT

The print icon lists a web address where the template for that particular step can be downloaded and printed out.

WEB

The web icon lists a web address where more information on that particular step can be found. A good example of this would be an online tutorial for soldering when the step calls for parts to be soldered.

WHY?

The why icon goes into detail on why a step is necessary. This is helpful when you can't see how each piece relates to the whole project. Any additional or helpful information will also be found here.

TOOLS YOU'LL NEED

All the tools you'll need to construct the rocket can set you back a few paychecks depending on what kind of shop you've got in your garage and what kind of tools you've stocked it with, if any. Most of the tools used in this book can be substituted for less expensive ones. It's all a balance between connivance and cost.

$$$



Nothing cuts through PVC pipe and plastic like an electric miter saw. If you're looking to make fast and accurate cuts, this is the tool you'll need. I use an 80 tooth blade specifically designed for cutting plastic, the cuts are clean and quick and to me, worth every penny. Saws range from $100 to $600 depending on the size of the blade and the options on the saw. Blades can easily cost $150 depending on the quality of the blade, the size and the number of teeth.

$





A simple $20 hacksaw can replace the miter saw but the accuracy of your cuts will suffer and each cut, especially when cutting 3" thick solid plastic rods, will take a tremendous amount of labor.

A belt sander will make quick work of any sanding jobs. Models range from $100 to $400. A simple electric palm sander will work well and can be purchased for under $30. Of course the most inexpensive option is just a single sheet of sand paper, but this is the most labor intensive option as well.





A bench grinder is only used in a few steps during the construction of the rocket, mainly in grinding down the aluminum rod used to make the core of the engine. Although they are relatively inexpensive, the belt sander will do good double duty here and easily take the place of the bench grinder. So if you don't already have one there's really no need to get one.

A good drill press is one of the most important tools you'll need to make the rocket in this book. A drill press will allow you to drill holes perfectly perpendicular to the working surface and at varying depths. This will be very important when drilling holes in the apogee detector where accuracy is imperative. Of course, a cordless or corded drill could take the place of the drill press but the extra material you'll go through mistake after mistake will probably pay for the drill press over a short amount of time. Drill presses range from $100 to $500. If you only get one tool, this is definitely the one to spend your money on.







$$$



A cordless drill is an inexpensive tool that will be used throughout the construction process. Hand held drills range in price from $50 to $300 and can be corded or cordless. Corded drills are less expensive than their cordless counterparts but not having a cord to deal with is a huge convenience.



A digital scale is another one of those tools that you don't want to skimp on. Luckily, prices on good digital scales have come down over the past several years. For this project you will need a scale with a resolution of 1/100 of a pound. Although you will only be using the scale to measure out the ingredients for the fuel, a good scale can turn out engines that work consistently well. It is possible that a beam balance scale could be used but since ingredients that aren't measured properly can turn an engine into a bomb, I wouldn't hold back on this one.



Soldering irons can run into the hundreds of dollars but since the soldering on this project is minimal, an inexpensive economy model is more than enough.



A stand mixer is convenient to have but definitely not necessary. A hand held mixer or whisk will work just as well and the labor is minimal.



A toaster oven is a must to dry out the potassium nitrate before you mix the fuel. This will increase the power of the engine and give you consistent results. Since toaster ovens are very inexpensive and can be purchased for around $20, there's no excuse to skip this one. A kitchen oven can be used in place of a toaster oven but it takes much longer to come up to temperature and uses considerably more energy.

The holes that need to be drilled in the rocket body, engine and apogee detector are only as good as your drill bits. Invest in a good set that goes from 1/16" to 1/2" in 32nd inch intervals. Typically these sets will come in 16 pieces and cost around $20. There are a few larger size bits that will be used at various steps. These can be purchased individually.

Other assorted hand tools, like screwdrivers, wire cutters and needle nose pliers are required at various steps. These tools are common enough that they're probably already in your tool box or garage.

$











I STILL HAVE ALL MY FINGERS



CHAPTER 1

MAKING THE ROCKET BODY

The rocket body is constructed out of cellular core ABS plastic pipe which is lightweight, strong and easy to work with. Three sections cut from one piece of pipe will make up all the sections of the rocket body. The lower section will hold the rocket engine, the upper section will hold the apogee detector, parachute piston and parachute, and the nosecone ring will hold the nosecone to the rocket.



INSTRUCTIONS 01

Purchase the following part:

- One 8' section of 3" diameter cellular core ABS.

MATERIALS

One 8' section of 3" diameter cellular core ABS plastic pipe from a home improvement store or plumbing supply house.

WHY?

Cellular core ABS has thousands of tiny air pockets in the wall of the pipe which makes it strong, lightweight and easy to work with.

WEB

www.homedepot.com part number 193828



INSTRUCTIONS 02

Put a 6' to 8' long piece of steel strut channel along the length of ABS pipe. Mark a line running down the pipe with a silver *Sharpie* marker. This line will be the center line that all the hole templates refer to. It will ensure that all the holes drilled in the pipe as well as the fins line up properly.

MATERIALS

One 6' to 8' length of steel strut channel.
Silver *Sharpie* or similar permanent marker.

OPTIONS

A straight edge, tape measure or chalk line can be used to mark the center line on the ABS pipe instead of the strut channel.

WHY?

Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly on the rocket body.



INSTRUCTIONS 03

Download and print out three templates:
- *Fin Hole Top Template 11x17*
- *Fin Hole Bottom Template 11x17*
- *Coupling Bolt Template 11x17*

The templates will need to be printed on 11x17 paper. If you printer doesn't print that size, copies can usually be made at a copy store or office supply store for a nominal fee.

MATERIALS Printer that can handle 11x17 paper.
Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 04

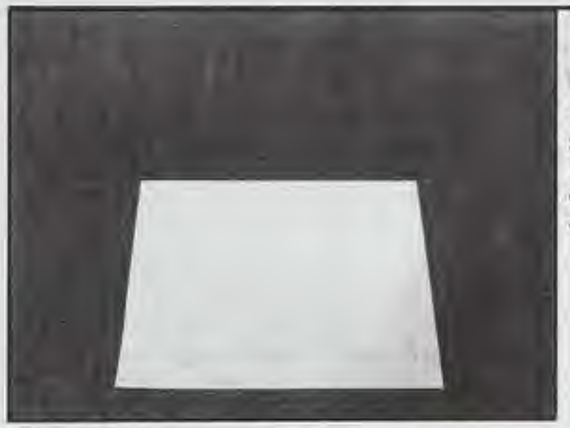
It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



INSTRUCTIONS 05

Carefully cut out all three templates as accurately as possible.

MATERIALS Razor blade or scissors.
Straight edge ruler.



INSTRUCTIONS 06

Place the *Fin Hole Bottom Template* on your work surface. Notice the center line going up through the drawing. You can see arrows with the letters CL next to them. Make sure the arrows on the center line are facing up.



INSTRUCTIONS 07

Place the *Fin Hole Top Template* above the *Fin Hole Bottom Template* . Make sure the center lines in each drawing are facing up and the top one lines up with the bottom one.

WHY? Putting these two templates together is the only way to accurately drill the holes for the 16" fins.



INSTRUCTIONS 08

Using scotch tape, tape the two templates together. Make sure the center lines in each drawing are facing up and the top one lines up with the bottom one.

MATERIALS Scotch tape.

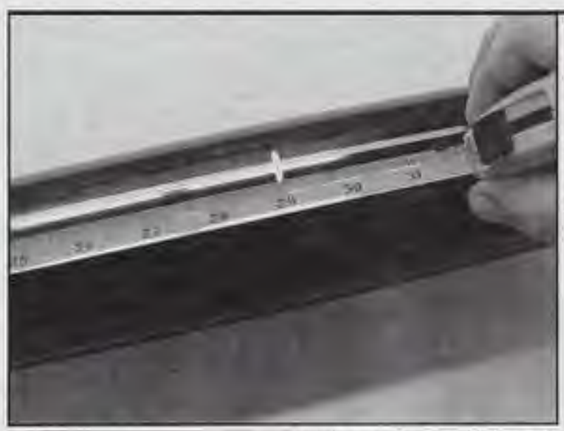


INSTRUCTIONS 09

Using a tape measure, mark a point on the pipe 37 1/2" from the bottom with a silver *Sharpie* marker.

MATERIALS Measuring tape or ruler.
Silver *Sharpie* or similar permanent marker.

WHY? You need to cut the ABS pipe into three sections. The lower section, the upper section and the nosecone ring.



INSTRUCTIONS 10

Using a tape measure, mark a point on the pipe 29" up from the mark in the last step (or 66 1/2" from the bottom of the pipe) with a silver *Sharpie* marker.

MATERIALS Measuring tape or ruler.
Silver *Sharpie* or similar permanent marker

OPTIONS If you'd rather measure up from the bottom of the pipe, the measurement would be 66 1/2"

WHY? You need to cut the ABS pipe into three sections. The lower section, the upper section and the nosecone ring.



INSTRUCTIONS 11

Draw several arrows along the center line to indicate which direction is up.

MATERIALS

Silver *Sharpie* or similar permanent marker

WHY?

Once the pipe is cut, the arrows will let you know which side of the pipe is up so the three pieces will fit together properly.



INSTRUCTIONS 12

Take the two templates that were taped together, the *Fin Hole Top Template* and *Fin Hole Bottom Template*, and place them on the bottom of the pipe. Make sure the bottom of the template lines up with the bottom of the pipe and the center line, marked CL on the drawing, lines up with the center line on the pipe.

WHY?

The holes from this template will determine where the fins go on the rocket body. It is important that the center line on the template and the center line on the pipe line up.



INSTRUCTIONS 13

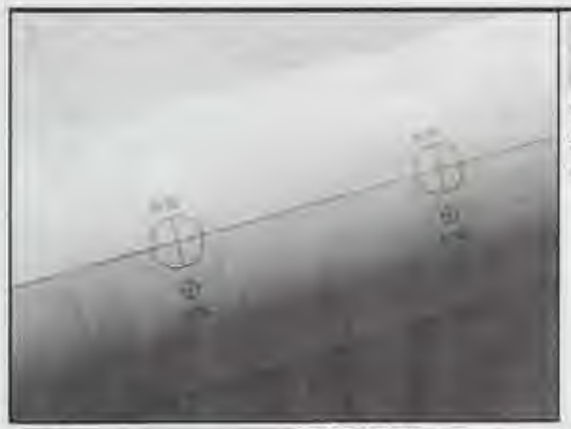
Once the template is in position, tape the template to the pipe then fold the template around the pipe and tape it together. Make sure the lines on either edge of the template line up with each other when you wrap it around the pipe.

MATERIALS

Scotch tape.

WHY?

It is very important that the lines on either edge of the pipe line up with each other when you wrap the template around the pipe. This will ensure that all the holes are parallel with the pipe and in the correct location.



INSTRUCTIONS 14

Tape over each circle on the template with Scotch tape and along the seam where the two edges of the template meet.

MATERIALS

Scotch tape.

WHY?

There is a half circle on both sides of the template edges. They are there to help you line up the template correctly.

WHY?

The circles on the template need to be taped so that when the template is drilled the paper won't rip.



15 INSTRUCTIONS

Tape the top of the template to the pipe.

MATERIALS Scotch tape.

WHY? The template needs to be securely attached to the pipe so it won't move during drilling.

16 INSTRUCTIONS



The *Fin Hole Templates* should now look like this when taped to the bottom of the pipe.



17 INSTRUCTIONS

Take the *Coupling Bolt Template* and align the hatched section of the template with the mark you made in step #9 that was 66 1/2" up from the bottom of the pipe. Make sure the center line on the template, marked with a *CL*, lines up with the center line on the pipe.

WHY? The holes from this template will determine where the coupling gets attached to the rocket body. It is important that the center line on the template and the center line on the pipe line up.

WHY? The *hatched* section of the template is the section that is filled with small parallel lines.

18 INSTRUCTIONS



Once the template is in position, tape the template to the pipe.

MATERIALS Scotch tape.



INSTRUCTIONS 19

Fold the template around the pipe and tape it together. Make sure the lines on either edge of the template line up with each other when you wrap it around the pipe.

MATERIALS

Scotch tape.

WHY?

It is very important that the lines on either edge of the template line up with each other when you wrap the template around the pipe. This will ensure that all the holes are parallel with the pipe and in the correct location.



INSTRUCTIONS 20

Tape over each circle on the template edge and along the seam where the two ends of the template meet.

MATERIALS

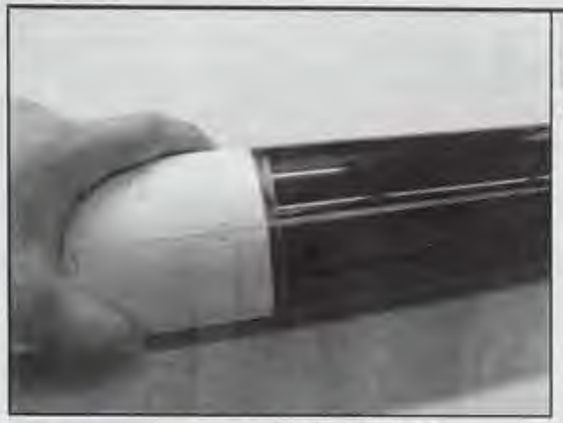
Scotch tape.

WHY?

There is a half circle on both sides of the template edges. They are there to help you line up the template correctly.

WHY?

The circles on the template need to be taped so that when the template is drilled the paper won't rip.



INSTRUCTIONS 21

Tape the top of the template to the pipe.

MATERIALS

Scotch tape.

WHY?

The template needs to be securely attached to the pipe so it won't move during drilling.



INSTRUCTIONS 22

Using a 3/16" drill bit, carefully drill all 12 holes marked 3/16" on the *Fin Hole Templates*.



WHY?

The bolts that hold the fins to the rocket body will go through these holes. Drill them as accurately as possible



INSTRUCTIONS 23

Using a 17/64" drill bit, carefully drill all 4 holes marked 17/64" on the *Fin Hole Templates*.

WHY? The bolts that hold the engine will go through these holes. Drill them as accurately as possible.



INSTRUCTIONS 24

Using a 9/16" spade bit, carefully drill all 12 holes marked 9/16" on the *Fin Hole Templates*.

WHY? These holes will be used to tighten the nuts that hold the fins to the rocket body. Drill them as accurately as possible.

WHY? A spade bit is used for fast drilling of holes in wood and plastic. Spade bits have a forged, flat paddle with a guide point and cutting edges on either side.



INSTRUCTIONS 25

Using a 9/32" drill bit, carefully drill all 12 holes marked 9/32" on the *Coupling Bolt Template*.

WHY? The bolts that hold the apogee detector will go through these holes. Drill them as accurately as possible.



INSTRUCTIONS 26

Using a 5/32" drill bit, carefully drill the hole marked 5/32" on the *Coupling Bolt Template*.

WHY? The safety pin that is used to arm the apogee detector will go through this hole. Drill it as accurately as possible.



INSTRUCTIONS 27

Using an electric miter saw, cut the pipe at the 66 1/2" mark from step #10.



OPTIONS A pipe cutter or a hacksaw can be used in place of an electric miter saw.



INSTRUCTIONS 28

Using an electric miter saw, cut along the hatched line on the *Coupling Bolt Template*. The hatched area is 1/8" thick, the same thickness as most saw blades.



OPTIONS A pipe cutter or a hacksaw can be used in place of an electric miter saw. However, two cuts will have to be made on this step since the cut is 1/8" thick.



INSTRUCTIONS 29

you should now have three pieces of pipe that look like this. The nosecone ring will be cut in the next few steps.

INSTRUCTIONS 30

Take the piece of pipe without any templates on it and mark a point 1/2" up from the edge cut in step #27.

MATERIALS Measuring tape or ruler.
Silver *Sharpie* or similar permanent marker.

WHY? This 1/2" piece of pipe will be the ring that holds the nosecone to the rocket. Use the piece of pipe right above the cut made in step #27 so the two edges will match perfectly.



INSTRUCTIONS 31

Mark an arrow on the center line below the 1/2" cut mark so you will know which side is up once this small piece is cut from the pipe.

MATERIALS

Measuring tape or ruler.
Silver *Sharpie* or similar permanent marker.

WHY?

This 1/2" piece of pipe will be the ring that holds the nosecone to the rocket. Use the piece of pipe right above the cut made in step #27 so the two edges will match perfectly.



INSTRUCTIONS 32

Using an electric miter saw, cut the 1/2" section from the bottom of the pipe.

OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.

WHY?

This 1/2" piece of pipe will be the ring that holds the nosecone to the rocket. Use the piece of pipe right above the cut made in step #27 so the two edges will match perfectly.



INSTRUCTIONS 33

Cut a small notch along the center line on the bottom of the 1/2" pipe ring using a bench mounted grinder.

OPTIONS

You can use a hacksaw or bastard file in place of a bench mounted grinder.

WHY?

Eventually this piece, along with the other parts of the rocket body, will be sanded and painted. The notch on the pipe will be an indicator of where the center line is as well as which end is up.



INSTRUCTIONS 34

Cut a small notch along the center line on the top and bottom of the lower body section using a bench mounted grinder.

OPTIONS

You can use a hacksaw or bastard file in place of a bench mounted grinder.

WHY?

Eventually this piece, along with the other parts of the rocket body, will be sanded and painted. The notch on the pipe will be an indicator of where the center line is as well as which end is up.



INSTRUCTIONS 35

Cut a small notch along the center line on the top and bottom of the upper body section using a bench mounted grinder.



OPTIONS You can use a hacksaw or bastard file in place of a bench mounted grinder.

WHY? Eventually this piece, along with the other parts of the rocket body, will be sanded and painted. The notch on the pipe will be an indicator of where the center line is as well as which end is up.



INSTRUCTIONS 36

Remove the templates and lightly sand the edges of each section of pipe with 600 grit sand paper.



MATERIALS 600 Grit sand paper.

WHY? Sanding the pipe will remove any burrs on the edges as well as prepare the surface of the pipe to be painted.



INSTRUCTIONS 37

At this point the lower body section, the upper body section and the nosecone ring have all been completed. You can now paint the rocket body sections any color you'd like.
To paint the rocket, lightly sand the plastic pipe with 600 grit sand paper. Next, wipe down the pipe with rubbing alcohol, this will remove any grease or oil. Finally paint the rocket any color you'd like with spray paint.

MATERIALS Rubbing alcohol.
600 Grit sand paper.
Spray paint.

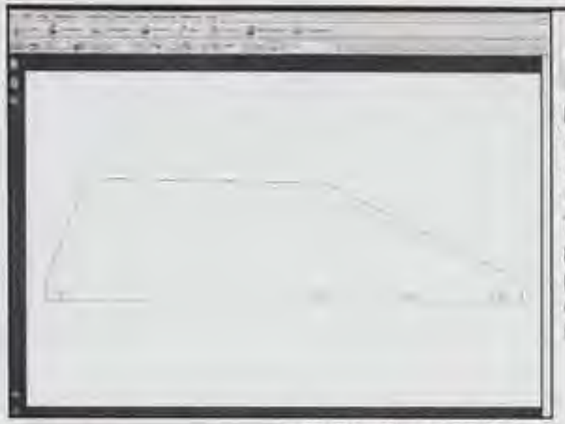
OPTIONS It's not necessary to paint the rocket at all.



CHAPTER 2

MAKING THE FINS

The fins are an important aspect of the rocket's overall design. They ensure the rocket's path through the air will be efficient and in the correct direction. The fins are made from high density polyethylene, HDPE, and are bolted in place along an aluminum u-channel. The resulting design is strong, impervious to moisture and can handle dozens of rough landings.



INSTRUCTIONS 01

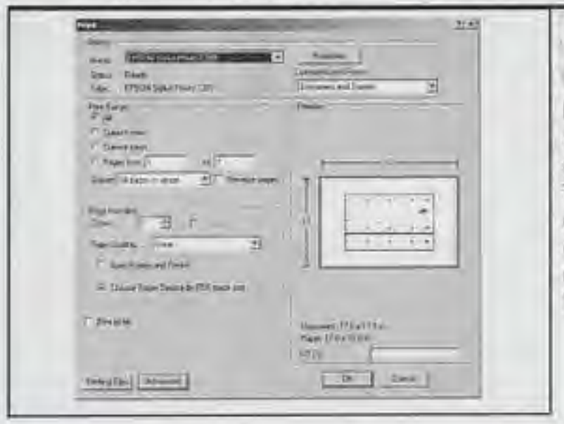
Download and print out three templates:
- *Bulkhead Templates 8.5 x 11*
- *Fin Template 11x17*
- *Fin Channel Template 11 x 17*

Two of the three templates will need to be printed on 11x17 paper. If you printer doesn't print that size, copies can usually be made at a copy store or office supply store for a nominal fee.

MATERIALS Printer that can handle 11x17 paper.
Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 02

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting correctly, check the scaling dialog box first.



INSTRUCTIONS 03

Purchase the following parts:
- Two 4" x 48" x 1/4" HDPE sheets.

MATERIALS Two 4" x 48" x 1/4" high density polyethylene (HDPE) sheets.

OPTIONS 1/4" Plywood can be used instead of the HDPE sheets but plywood has the tendency to warp in humid conditions and is not as sturdy as plastic.

WEB www.mcmaster.com part number 8671K69.



INSTRUCTIONS 04

Measure 24" on one of the HDPE sheets and mark it using a black *Sharpie* marker.

MATERIALS Black Sharpie or similar permanent marker.

WHY? The 48" long HDPE sheets need to be cut down to a more manageable size. Plus, having four sheets will make cutting out four fins much easier.

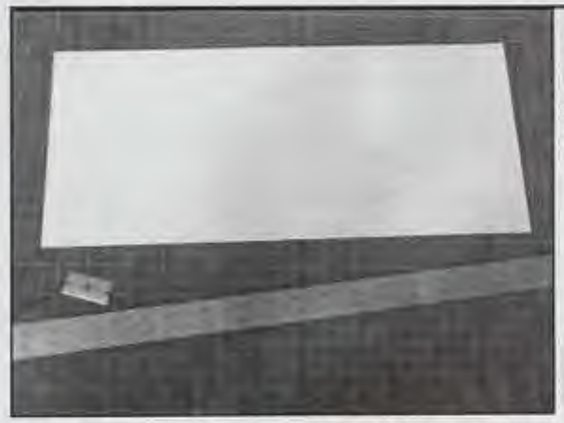


INSTRUCTIONS 05

Stack the two HDPE sheets together and then cut them in half at the 24" mark.



WHY? The 48" long HDPE sheets need to be cut down to a more manageable size. Plus, having four sheets will make cutting out four fins much easier.



INSTRUCTIONS 06

Cut along the bottom edge of the fin on the *Fin Template*.



MATERIALS Razor blade or scissors.
Straight edge ruler.



INSTRUCTIONS 07

Lay the *Fin Template* on top of one of the four HDPE sheets. Make sure the bottom of the fin on the *Fin Template* is lined up with the bottom edge of the HDPE sheet.



INSTRUCTIONS 08

Using a center punch, mark the six corners that make up the edge of the fins. Make sure not to move the *Fin Template* as you proceed to the next step.



OPTIONS

A sharp nail can be used in place of a center punch.



INSTRUCTIONS 09

Using a center punch, mark all four of the 1/2" holes on the *Fin Template*.

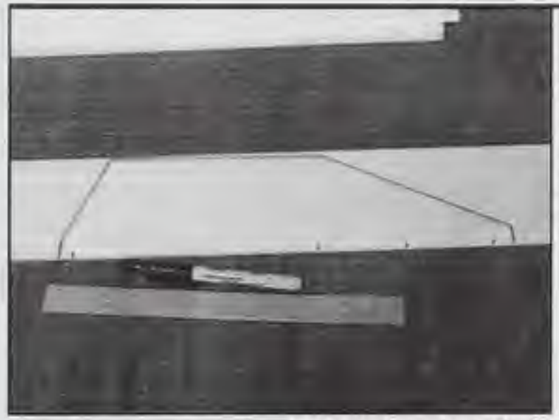


OPTIONS

A sharp nail can be used in place of a center punch.

WHY?

Because the bolt heads that hold the fins on the rocket body will sit on the bottom of the aluminum channel, four 1/2" holes will have to be drilled in the fins to accommodate them.



INSTRUCTIONS 10

Using the punch marks from the center punch as a guide, trace the outline of the fin shape on the HDPE sheet. Mark four small lines on the punch marks for the 1/2" holes with a black *Sharpie* marker.

MATERIALS

Black *Sharpie* or similar permanent marker.
Straight edge ruler.

WHY?

Cutting all the fins together will ensure they are all the same size and weight. This will greatly improve the aerodynamics of the finished rocket.

WHY?

Because the bolt heads that hold the fins on the rocket body will sit on the bottom of the aluminum channel, four 1/2" holes will have to be drilled in the fins to accommodate them.



INSTRUCTIONS 11

Stack the four HDPE sheets together with the fin outline on top. Put the HDPE sheets on their side so that the bottom edges all line up. Clamp the four HDPE sheets together.



INSTRUCTIONS 12

Using an electric miter saw, cut out the fin shape from the HDPE sheets. Cut all four pieces together, moving the clamps as you move around the stack of HDPE sheets to make room for the saw blade.

OPTIONS

A hacksaw or miter box saw can be used in place of an electric miter saw.

WHY?

Cutting all the fins together will ensure they are all the same size and weight. This will greatly improve the aerodynamics of the finished rocket.



INSTRUCTIONS 13

Once the fins have been cut out from the block of four HDPE sheets, you should have a stack that looks like this. Keep the clamps on the fins as you proceed to the next step.

WHY?

Cutting all the fins together will ensure they are all the same size and weight. This will greatly improve the aerodynamics of the finished rocket.



INSTRUCTIONS 14

Using a belt sander, sand all the edges of the fins smooth. The fins should all be the same size at the end of this step.

OPTIONS

You can substitute a hand held electric sander for the belt sander or if you're really brave, a sheet of sandpaper, but this step will take you quite a bit of time and elbow grease.

WHY?

Sanding all the fins together will ensure they are all the same size and weight. This will greatly improve the aerodynamics of the finished rocket.



INSTRUCTIONS 15

Clamp the fins to a drill press and cut out 1/2" diameter half circles on the four punch marks from step #9. The easiest way to drill out the half circles is to use a 1/2" *forstner* bit.

OPTIONS You could use a hacksaw to cut the notches required in this step. Just try to stay as close to the 1/2" half circle mark as possible.

WHY? Because the bolt heads that hold the fins on the rocket body will sit on the bottom of the aluminum channel, four 1/2" holes will have to be drilled in the fins to accommodate them.

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



INSTRUCTIONS 16

The finished HDPE fins should now look like this.



INSTRUCTIONS 17

The *Fin Channel Template* needs to be folded exactly on its center line. Take a razor and cut the center line on the template. Only cut the center line at this time, the rest of the template will be cut out later.

MATERIALS Razor blade or scissors.
Straight edge ruler.

WHY? The *Fin Channel Template* needs to be folded exactly along the center line. To do this we'll cut the center line, tape it with scotch tape and then fold it easily once the rest of the template is cut out.



INSTRUCTIONS 18

Put a piece of scotch tape along the back of the template over the line that was cut. Then, cut out the rest of the template. The template will now fold easily and exactly on the center line.

MATERIALS Razor blade or scissors.
Straight edge ruler.
Scotch tape.

WHY? The *Fin Channel Template* needs to be folded exactly along the center line. To do this we'll cut the center line, tape it with scotch tape and then fold it easily once the rest of the template is cut out.



INSTRUCTIONS 19

Purchase the following part:
• One 8' length 3/4" x 3/4" aluminum u-channel.

Cut the u-channel into four 16" pieces using a hacksaw or reciprocating saw.

MATERIALS 3/4" x 3/4" x 8' Aluminum u-channel:-

WHY? This sturdy aluminum u-channel will be used to attach the fins to the rocket body.

WEB www.mcmaster.com part number 9001K32.



INSTRUCTIONS 20

Hold all the aluminum u-channel pieces together and using a belt sander, grind down the edges until they are all the same size and the edges are perpendicular to the channels. Don't worry if you need to reduce the length of the u-channels to do this, they were purposely cut 1/4" longer than they need to be.

OPTIONS A hand sander can be used in place of a belt sander but it will take you considerably longer and the finished product will not be as accurate.

WHY? Grinding all the u-channels together will ensure they are all the same size and weight. This will greatly improve the aerodynamics of the finished rocket.



INSTRUCTIONS 21

After you've finished sanding down one end of the u-channels, turn them around and sand down the other end. The finished u-channels should be between 15 3/4" and 16" but should not be shorter than 15 3/4".



INSTRUCTIONS 22

Lay the *Fin Channel Template* on one of the u-channels. Then, using a center punch, mark the center of each of the four 3/16" holes on the bottom of the u-channel. Make sure the template is lined up with the right edge of the u-channel. Repeat with the other three u-channels.

OPTIONS A sharp nail can be used in place of a center punch.

WHY? These holes must be drilled as acutately as possible. Using a center punch will insure that the mark to drill the hole is exactly were you want it to be.



INSTRUCTIONS 23

Using a center punch, mark the holes on the side of the u-channel where the 6-20 x 3/8"self tapping screws will go. Make sure to line up the template to the right edge on the u-channel as you did in the previous step.



OPTIONS

A sharp nail can be used in place of a center punch.



INSTRUCTIONS 24

Put all four u-channels in a drill press vise, bottom side up, and drill out the four 3/16" holes on each channel. Make sure to drill the holes as accurately as possible keeping to the punch marks made in step #22. Use a lubricating oil like WD-40 to prevent the drill bit from overheating.



MATERIALS

WD-40 Lubricating oil or similar.

OPTIONS

A hand held drill can be used in place of a drill press as long as the holes are drilled as accurately as possible.



INSTRUCTIONS 25

Dilute some solvent based parts cleaning solution in a bucket with water according to the manufacturers instructions. Clean the u-channels and then dry them throughly.



MATERIALS

Solvent based parts cleaning solution.

OPTIONS

With a little effort, a good grease cutting dish soap will work in place of the parts cleaning solution.



INSTRUCTIONS 26

The finished u-channels should now look like this.

WHY?

The holes in the u-channels and the holes drilled in the rocket body in chapter 1 need to line up perfectly. There's not much room to spare since the fins require a tight fit to work properly.



INSTRUCTIONS 27

Purchase the following parts:
- Sixteen 8-32 steel machine hex nuts.
- Sixteen 8-32 x 1/2" stainless steel hex screws.

MATERIALS Sixteen 8-32 Steel machine screw hex nuts.
Sixteen 8-32 x 1/2" Stainless steel machine hex screws.

WHY? The 8-32 x 1/2" stainless steel machine hex screws have a very narrow head which fits perfectly inside the aluminum u-channels. Stainless steel threads are stronger than steel and have less of a tendency to strip when stressed.

WEB www.mcamster.com part number 90480A009.
www.mcmaster.com part number 92314A194.



INSTRUCTIONS 28

Put a 8-32 x 1/2" machine screw through one of the 3/16" holes on the fin channel. Thread an 8-32 hex nut on the other end and tighten it with a socket or wrench. The 8-32 x 1/2" hex screw has a narrow head and will fit perfectly inside the fin channel. Repeat until all sixteen 3/16" holes in the fin channels have screws and nuts installed in them.

WHY? The 8-32 x 1/2" stainless steel machine hex screws have a very narrow head which fits perfectly inside the aluminum u-channels. Stainless steel threads are stronger than steel and have less of a tendency to strip when stressed.



INSTRUCTIONS 29

Put a squirt of epoxy over each screw head inside one of the fin channels. Immediately proceed to the next step.

MATERIALS *Loctite* E-00CL fast setting epoxy.
Loctite applicator gun.
Loctite mixing nozzle.

OPTIONS Since the purpose of the epoxy is just to hold the screw heads in the fin channel and prevent them from moving when the fins are attached to the rocket body, a less expensive epoxy can definitely be substituted for the epoxy in this step. The gun and mixing nozzle just make it easier.

WEB www.mcmaster.com part number 6430A16.
www.mcmaster.com part number 74695A71.
www.mcmaster.com part number 74695A12.



INSTRUCTIONS 30

Press a fin down into the fin channel. Make sure the four half holes that were drilled into the fin in step #15 line up with the machine screw heads in the fin channel. Align the front edge of the fin with the front edge of the fin channel.

WHY? The epoxy is not there to hold the fin in the fin channel, its only purpose is to keep the machine screws from moving when the hex nuts are removed and the fin is attached to the rocket body in a later step.



INSTRUCTIONS 31

Turn the fin over and gently tap the bottom of the fin channel with a hammer until the fin sits all the way inside the fin channel. Wipe off any epoxy that squeezes out of either end. Repeat this step with all four fins.



INSTRUCTIONS 32

When you are finished, the four fins should look like this.

WHY? Take you time making the fins. a good job will go a long way in ensuring the rocket is aerodynamically stable.



INSTRUCTIONS 33

Purchase the following part:
• Three 6-20 x 3/8" self tapping screws.

Install three 6-20 x 3/8" screws on the side of each fin channel at the punch marks made in step #23. Use a cordless drill with a philips bit to install the self tapping screws.

MATERIALS Twelve 6-20 x 3/8" self tapping screws.

WHY? These three screws are what really hold the fin in the fin channel where the machine screws on the bottom edge hold the fin channel to the rocket body.

WEB www.mcmaster.com part number 94060A146.



INSTRUCTIONS 34

Once the epoxy has hardened, remove all sixteen 8-32 hex nuts from the bottom of the fin channel and put them aside to be used at a later date.

WHY? The hex nuts that will hold the fin channel to the rocket body need to have a locking washer on them so the fins will not vibrate loose. Installing a separate nut and washer is problematic so an 8-32 steel hex nut with a tooth washer attached to it will be used.



INSTRUCTIONS 35

Insert the machine screws on the bottom of the fin channel into the holes in the lower rocket body section from the previous chapter. I've painted my lower rocket body section orange.

WHY? This is where all the careful work printing out templates and drilling holes pays off.



INSTRUCTIONS 36

To attach the fins to the rocket body, a normal 11/32" nut driver won't work for two reasons, it's too short and the head is too wide to fit through the 9/16" holes that were drilled in the rocket body earlier. In order to easily attach the fins to the rocket body you'll need three tools. A standard six point 1/4" drive socket, 11/32", a 1/4" wobble drive extension that will be used to make up for misalignment when starting the nuts and a long 1/4" square driver that will be used to tighten the nuts.
It might seem complicated but it's just three simple tools that will save you tons of time. Review the next few steps and it will become clear.

MATERIALS
1/4" Drive socket extention x 11"
1/4" Square driver, long, 9 1/2"
6 Point standard 1/4" drive socket, 11/32"

WEB
www.mcmaster.com part number 5521A44.
www.mcmaster.com part number 5521A67.
www.mcmaster.com part number 5543A26.



INSTRUCTIONS 37

Purchase the following part:
• Sixteen 8-32 steel hex nuts with tooth washers.

Put an 8-32 hex nut with tooth washer in the 11/32" socket and feed the socket through the 9/16" hole on the opposite side of the rocket body. Use the wobble driver to start the nut then tighten it with the standard socket driver. Repeat with all four nuts on the fin and with all four fins on the rocket.

MATERIALS Sixteen 8-32 steel hex nut with tooth washers.

WHY? Don't use a ratchet to tighten the hex nuts but tighten them as tight as you can by hand.

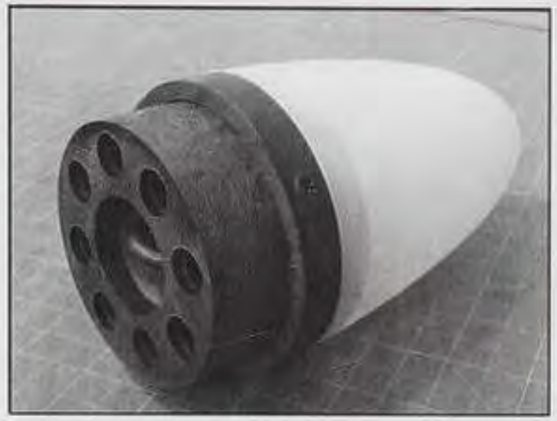
WEB www.mcmaster.com part number 90675A007.



INSTRUCTIONS 38

The finished lower body section should look like this. The fins should be solidly attached to the body.

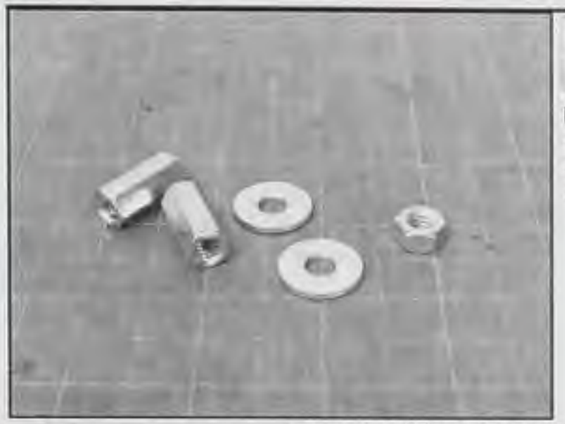
WHY? The fins can be painted the same way the rocket body was painted. White fins go well with my orange and white color scheme so I've left them un-painted on purpose.



CHAPTER 3

MAKING THE NOSECONE

The nosecone is constructed from an inexpensive plastic wine glass with the stem and base removed. A plastic support structure is necessary to hold the wine glass securely to the rocket body. Some delrin plastic rod will be used to fabricate the nosecone support.



INSTRUCTIONS 01

Purchase the following parts:
- Two 1/4-20 x 7/8" coupling nuts.
- Two round steel washers for 1/4" screws.
- One 1/4-20 steel hex nut.

MATERIALS

Two 1/4-20 x 7/8" steel coupling nuts.
Two round steel washers for 1/4" screws.
One 1/4-20 steel hex nut .

WEB

www.mcmaster.com part number 90264A435.
www.mcmaster.com part number 91090A107.
www.mcmaster.com part number 93827A211.



INSTRUCTIONS 02

Purchase the following parts:
- One 1/4-20 x 3/8" button head hex screw.
- One 1/4-20 x 4" aluminum fully threaded stud.
- One 1/4-20 x 1 1/2" steel eyebolt.

MATERIALS

One 1/4-20 x 3/8" button head hex screw.
One 1/4-20 x 4" aluminum fully threaded stud.
One 1/4-20 x 1 1/2" steel eyebolt.

WEB

www.mcmaster.com part number 91255A535.
www.mcmaster.com part number 91090A107.
www.mcmaster.com part number 9489T118.



03

INSTRUCTIONS

Purchase the following part:
- Four #6 x 1" steel wood screws.

MATERIALS

Four #6 x 1" steel wood screws.

WEB

www.mcmaster.com part number 90252A106.



04

INSTRUCTIONS

Purchase the following part:
- One 16 ounce plastic wine glass.

MATERIALS

One 16 ounce plastic wine glass.

OPTIONS

Plastic wine glasses come in a variety of shapes and sizes and are available online for a very reasonable cost. Any shape wine glass can be substituted for the one in this step as long as the outside diameter is 3 1/2".

WEB

www.kidsmartliving.com part number CR062-612.



05

INSTRUCTIONS

Remove the base from the plastic wine glass.

WHY?

The wine glass is made from polypropylene which is flexible and very easy to machine.



06

INSTRUCTIONS

Using a belt sander, sand down the stem of the plastic wine glass until it is level with the bottom of the glass.

OPTIONS

A hand sander or sandpaper can easily be used in place of a belt sander.



INSTRUCTIONS 07

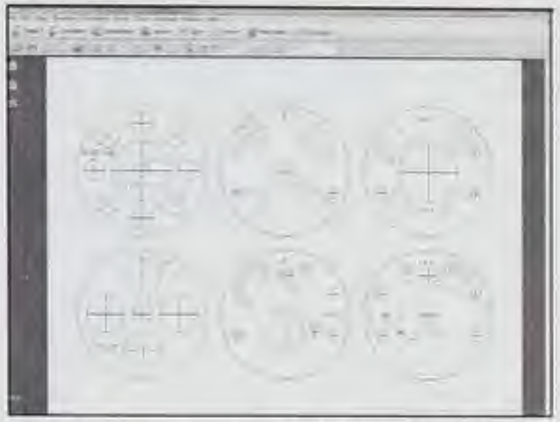
The bottom of the wine glass should now look like this.

WHY? A 1/4-20 x 3/8" button head hex screw will go through the hole on the *bottom* of the wine glass or the *top* of the nosecone to attach the nosecone to the nosecone assembly.



INSTRUCTIONS 08

Using a cordless drill and a 1/4" bit, drill out the hole on the top of the nosecone.



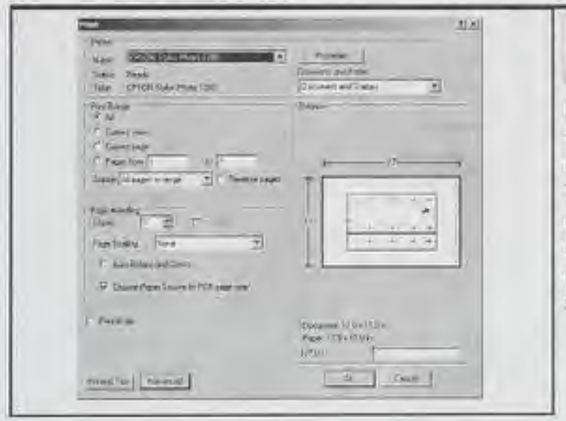
INSTRUCTIONS 09

Download and print out the following template:
- *Bulkhead Template 8.5 x 11*

MATERIALS Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates take all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 10

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



INSTRUCTIONS 11

Cut out the template marked nosecone as accurately as possible.

MATERIALS

Razor blade or scissors.

INSTRUCTIONS 12

Purchase the following part:

- 2" length of 3" diameter black delrin rod.



MATERIALS

3" Diameter delrin rod 2" long.

WHY?

Delrin is an inexpensive black thermoplastic that is easy to cut and machine. It is sturdy enough to act as the nosecone support.

WEB

www.mcmaster.com part number 9986K13.



INSTRUCTIONS 13

Using a belt sander, sand down the sides of the rod evenly so that it slips into the upper rocket body with a minimal amount of resistance. The rod shouldn't move when put in the rocket body but it shouldn't be excessively hard to pull out either. What you don't want is any lateral play or wiggle when the rod slips into the rocket body.

OPTIONS

A hand held sander or sand paper can be used in place of a belt sander. Just make sure the rod is sanded down evenly.

WHY?

The cellular ABS pipe used to make the rocket body in chapter 1 was designed for drainage, not rockets. The inside diameter of the pipe varies from batch to batch. Sanding down the rod will make a custom fit for the nosecone support inside the upper rocket body.

INSTRUCTIONS 14



The sanded rod should slip in snugly into the rocket body. Here you can see I've painted the upper section of the rocket body white.

WHY?

You may notice that the rocket body in this picture looks a little beat up for being brand new. The truth is, this is the second time I wrote this chapter. The first time I accidentally deleted all the pictures when I thought I had backed them up. By the time I got to re-writing this chapter I had already completed the upper body section and didn't want to disassemble it for a single picture so I used an old rocket body instead. I guess the point of this story is, a backup isn't a backup unless it's in two places.



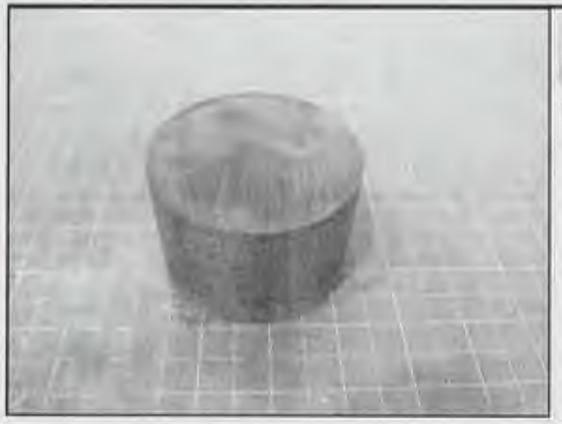
INSTRUCTIONS 15

Sand down both faces on the rod. Sand them just enough to make them smooth.



OPTIONS A hand held sander or sandpaper can be used in place of a belt sander.

WHY? It's important that each face of the rod is perpendicular to the side.



INSTRUCTIONS 16

The sanded rod should look like this.



INSTRUCTIONS 17

Line up the nosecone template on the delrin rod and mark the center point with a center punch.



OPTIONS A sharp nail can be used in place of a center punch.



INSTRUCTIONS 18

Turn the rod over and mark the center point as well as the eight outer circles.



OPTIONS A sharp nail can be used in place of a center punch.

WHY? The eight 1/2" diameter holes around the outside of the nosecone support are drilled to reduce weight and are OPTIONAL.



INSTRUCTIONS 19

Using a 1 3/8" forstner bit, drill a 1 3/8" hole 1 1/2" deep in the center of the rod.

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.

WHY? To save space in the rocket, the eyebolt that will attach the nosecone to the parachute will be put up inside the nosecone support.



INSTRUCTIONS 20

Turn the rod over and drill a 1/4" hole in the center of the rod.



INSTRUCTIONS 21

Using a 1/2" spade bit, drill out all eight holes around the exterior of the disc. Drill the holes all the way through the rod.

WHY? The eight 1/2" diameter holes around the outside of the nosecone support are drilled to reduce weight and are OPTIONAL.

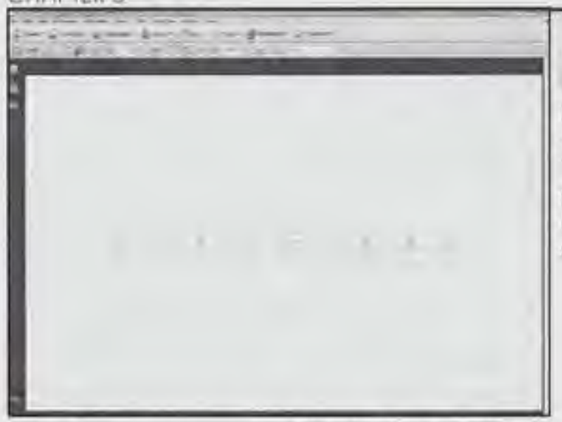
WHY? A spade bit is used for fast drilling of holes in wood and plastic. Spade bits have a forged, flat paddle with a guide point and cutting edges on either side.



INSTRUCTIONS 22

Put the 1/2" pipe section from chapter 1, step #33 on your work surface.

WHY? This 1/2" piece of pipe will be the ring that holds the nosecone section to the rocket.



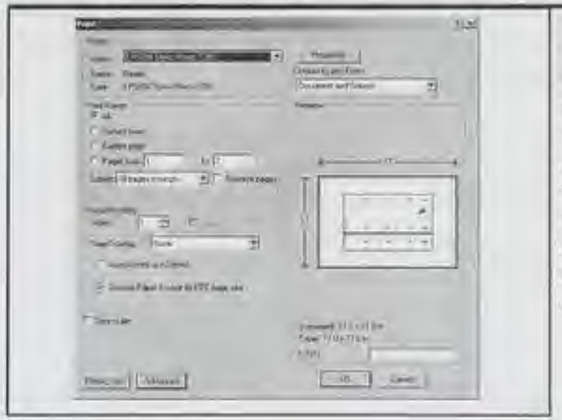
INSTRUCTIONS 23

Download and print out one template:
• *Nosecone Screw Template 11x17*
The template will need to be printed on 11x17 paper. If you printer doesn't print that size, copies can usually be made at a copy store or office supply store for a nominal fee.

MATERIALS Printer that can handle 11x17 paper.
Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 24

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



INSTRUCTIONS 24

Cut out the *Nosecone Screw Template* as accurately as possible.

MATERIALS Razor blade or scissors.
Straight edge ruler.



INSTRUCTIONS 26

Tape the template on the 1/2" pipe. Make sure the center line on the template lines up with the center line on the pipe. The center line on the template is marked with and arrow and the letters *CL*.

MATERIALS Scotch tape.

WHY? Screws will be put through the four holes from this template. The screws will hold the pipe to the nosecone support.

WHY? Just like constructing the rocket body, a center line is important to keep all the parts of the rocket lined up properly.



INSTRUCTIONS 27

Mark all four 1/8" holes on the 1/2" pipe with a center punch.

OPTIONS

A sharp nail can be used in place of the center punch.



INSTRUCTIONS 28

Drill all four holes with a 1/8" drill bit.



INSTRUCTIONS 29

Using a 3/8" step bit or 3/8" countersink bit, countersink the four 1/8" holes in the 1/2" pipe. This step is OPTIONAL. The countersunk holes will allow the screws to be flush with the exterior of the rocket.

OPTIONS

Any type of screw can be used in this step. It is not necessary that the screw head be flush with the exterior of the rocket. It's purely an aesthetic choice.

WHY?

The wood screws that will hold this piece of pipe to the plastic rod are pan head screws have a flat tapered head that will be flush with the exterior of the rocket when installed.

WEB

www.mcmaster.com part number 2846A22.



INSTRUCTIONS 30

Using a silver *Sharpie* marker, mark a point half way along the length of the plastic rod. Measure 1" down from the top or 1" up from the bottom.

MATERIALS

Silver *Sharpie* or similar permanent marker.



INSTRUCTIONS 31

Position the 1/2" pipe on the plastic rod so the notch cut in chapter 1, step #33 is lined up with the mark made in the previous step. Make sure the arrow on the 1/2" pipe is facing the 1/4" hole on the plastic rod. If you've painted this piece already, the arrow points away from the notch. Also make sure the center line on the ABS pipe is in between the 1/2" holes on the plastic rod. See the picture for reference.

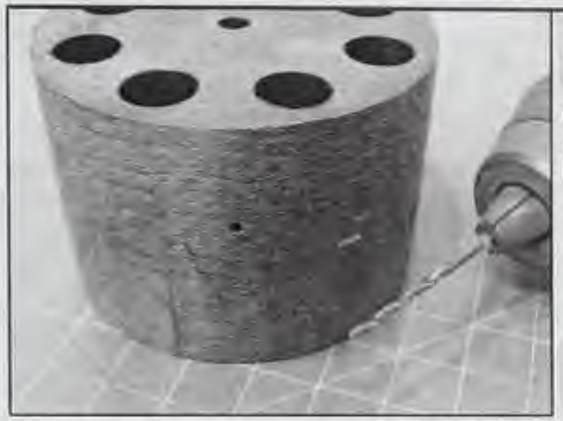
WHY? The portion of the plastic rod that slips into the rocket body and holds the nosecone firmly in place needs to be 1" long.



INSTRUCTIONS 32

Mark the plastic rod through all four 1/8" holes on the ABS pipe with a center punch.

OPTIONS A sharp nail can be used in place of the center punch.



INSTRUCTIONS 33

Drill all four holes on the plastic rod with a 3/32" drill bit. Drill the holes all the way into the 1 3/8" hole in the center of the plastic rod.

WHY? The four 3/32" holes will act as pilot holes for the wood screws that hold the 1/2" pipe to the plastic rod.



INSTRUCTIONS 34

Screw the 1/2" pipe to the plastic rod with four #6 x 1" flat head wood screws.



INSTRUCTIONS 35

Put a 1/4-20 hex nut all the way to the top of the threads of a 1/4-20 x 1 1/2" steel eyebolt. Next, put a 1/4" hole steel washer on the eyebolt.

WHY? The eyebolt will hold the nosecone to the parachute shock cord.



INSTRUCTIONS 36

Put the eyebolt through the 1 3/8" hole in the plastic rod and up through the 1/4" hole in the center of the plastic rod.

WHY? The eyebolt will hold the nosecone to the parachute shock cord.



INSTRUCTIONS 37

Put a drop of *Loctite* 272 thread locking fluid on the exposed threads of the eyebolt. Install a 1/4" steel washer and a 1/4-20 x 7/8" coupling nut on to the eyebolt. Tighten the coupling nut to the eyebolt with an adjustable wrench. Allow the *Loctite* to dry for 30 minutes.

OPTIONS A lock nut can be used in addition to the steel washer in place of the *Loctite* thread locking compound.

WEB More information about thread locking fluid can be found at www.wikipedia.org under *thread-locking fluid*.

WEB www.mcmaster part number 91458A650.



INSTRUCTIONS 38

Purchase the following part:
• One 4 1/2' length of 3" diameter PVC drain pipe.

Using an electric miter saw, cut a 1/2" piece of PVC drain pipe.

OPTIONS Even though it's the perfect size, I realize purchasing a 4 1/2' length of pipe only to use 1/2" of it is a bit excessive. 1/2" Masking tape will work just as well.

WHY? The inside diameter of the plastic wine glass is slightly larger than the outside diameter of the plastic rod. This difference can contribute to the nosecone moving during flight. The 1/2" section of PVC drain pipe prevents that from occurring.

WEB www.mcmaster.com part number 2426K24.



INSTRUCTIONS 39

Place the 1/2" drain pipe on the top of the 1/2" ABS pipe.

OPTIONS Even though it's the perfect size, I realize purchasing a 4 1/2' length of pipe only to use 1/2" of it is a bit excessive. 1/2" Masking tape will work just as well.

WHY? The inside diameter of the plastic wine glass is slightly larger than the outside diameter of the plastic rod. This difference can contribute to the nosecone moving during flight. The 1/2" section of PVC drain pipe prevents that from occurring.



INSTRUCTIONS 40

When the *Loctite* has had a chance to dry, thread a 1/4-20 x 4" fully threaded stud to the coupling nut on the face of the plastic rod. DO NOT USE *LOCTITE* ON THIS END OF THE THREADED STUD.

OPTIONS A steel threaded rod is a little less expensive than aluminum. The weight gain to the rocket is minimal.

WHY? The threaded stud will hold the wine glass on the top of the plastic rod securing the whole nosecone assembly together. It also makes for a convenient structure to attach other rocket electronics to.



INSTRUCTIONS 41

Read and understand step #42 before starting this step. Place a drop of *Loctite* 272 on the top of the threaded stud. Thread on a 1/4-20 x 7/8" coupling nut on to the top of the threaded stud.

WHY? The coupling nut on top of the threaded stud will hold the plastic wine glass tightly to the rest of the nosecone assembly and needs to be adjusted properly before the *Loctite* dries.

WEB www.mcmaster part number 91458A650.



INSTRUCTIONS 42

Place the plastic wine glass on the nosecone assembly. Look through the 1/4" hole on the top of the wine glass. You need to adjust the coupling nut so that it just touches the top of the wine glass. Move the coupling nut up or down until it is in the proper place.

WHY? The coupling nut on top of the threaded stud will hold the plastic wine glass tightly to the rest of the nosecone assembly and needs to be adjusted properly before the *Loctite* dries.



INSTRUCTIONS 43

When the coupling nut is in place near the top of the wine glass it should look like this.



INSTRUCTIONS 44

Let the *Loctite* dry throughly.

OPTIONS

A 1/4-20 hex nut and a lock washer could be used in place of the *Loctite*. Place the hex nut and lock washer under the coupling nut and then tighten them once the coupling nut is in place.

WHY?

The *Loctite* will hold the coupling nut firmly in place.



INSTRUCTIONS 45

Once the *Loctite* has dried, place the plastic wine glass on the nosecone assembly and secure it with a 1/4-20 x 3/8" button head hex screw.

OPTIONS

The nosecone can now be painted to match the rest of the rocket. Remember to mask the plastic rod when painting to maintain the snug fit it has inside the upper rocket body.



CHAPTER 4

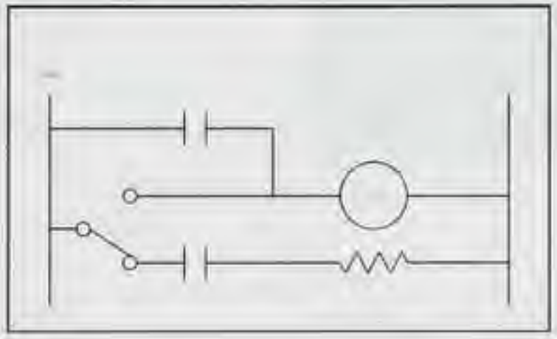
MAKING THE APOGEE DETECTOR PART 1

The apogee detector has multiple functions. It's an electro-mechanical device that detects when the rocket reaches apogee. It sends the signal to the parachute piston to eject the parachute and also acts as an anchoring point for the parachute piston and the parachute rigging. The lower portion of the detector centers the engine in the rocket and is the coupler between the lower section and the upper section of the rocket.

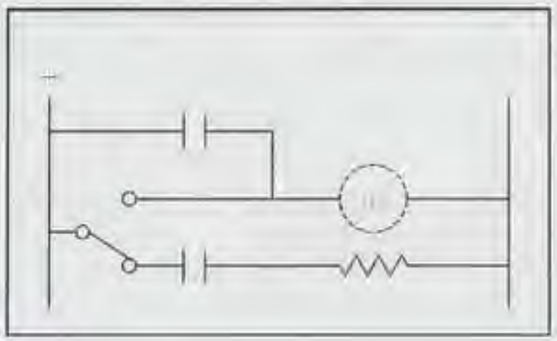
The original idea for the apogee detector came from my good friend Alberto Gassol. Even though many people said a device like this would never work we persisted in designing it anyway. A link to Alberto's website can be found in the Resources chapter at www.inverseengineering.com.

HOW DOES THE APOGEE DETECTOR WORK?

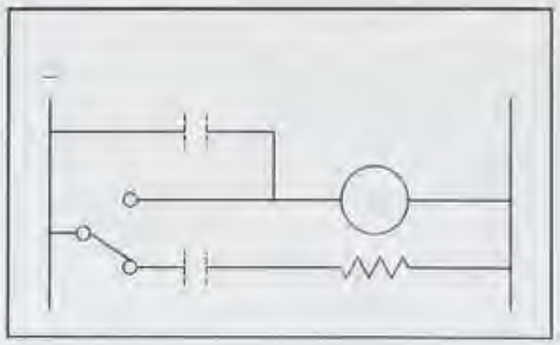
Alberto's original apogee detection circuit used an integrated circuit that required a substantial knowledge of electronic components and soldering. The apogee detector in this book uses off the shelf parts to keep construction simple and cost down. This simple circuit consists of a snap switch, three steel balls, a double pole double throw ice cube relay and a 9 volt battery.
Here's how it works.



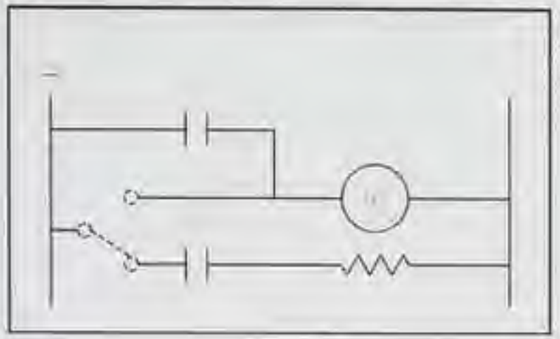
The apogee detector circuit looks like this.



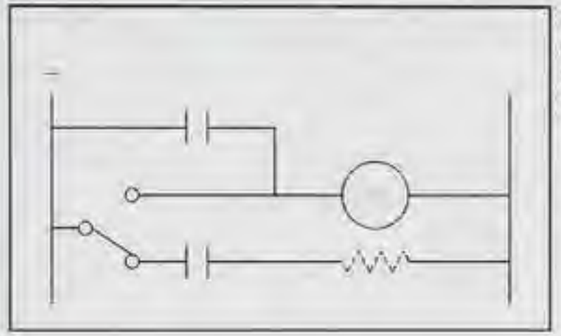
R1 is the relay coil and it has two normally open contacts. R1 is represented by a dashed line in this drawing.



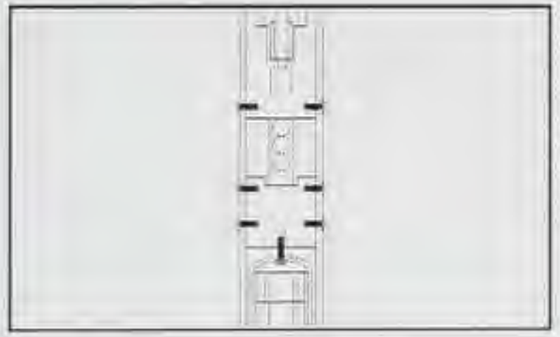
The two normally open contacts are represented by dashed lines in this drawing.



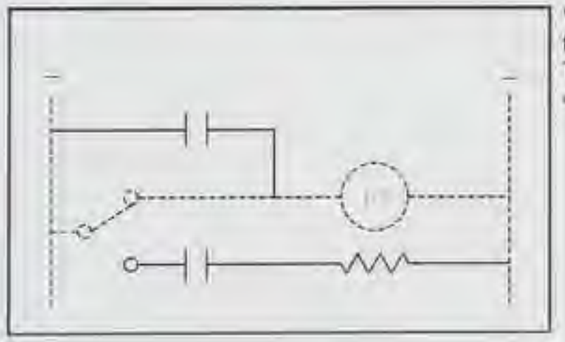
The snap switch activates the relay coil when the steel balls in the apogee detector close the switch. The snap switch is represented by a dashed line in this drawing.



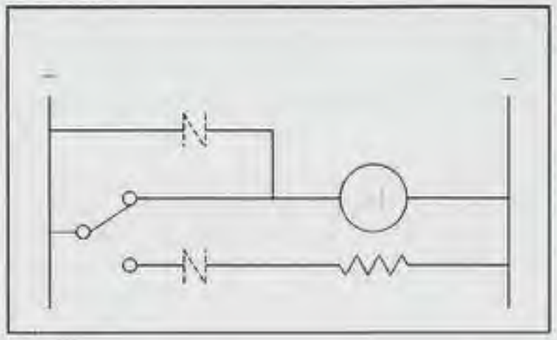
The ejection piston uses a small pyrogen to create hot gas that pushes out the parachute. The ejection piston igniter is represented by a dashed line in this drawing.



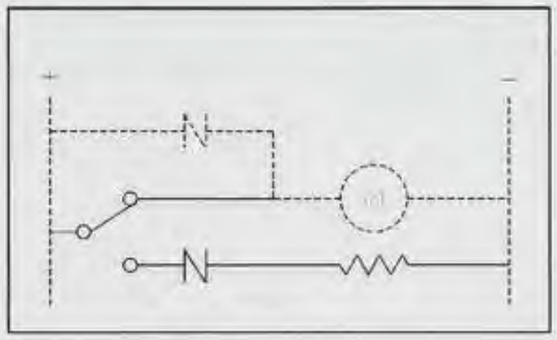
After the rocket takes off and the engine cuts out, the three steel balls move up to the top of the fiberglass chamber inside the apogee detector. This is because the drag on the outside of the rocket is greater than the drag on the steel balls inside the rocket. Unless acted on by an outside force, the steel balls would stay in this position until the rocket hit the ground.



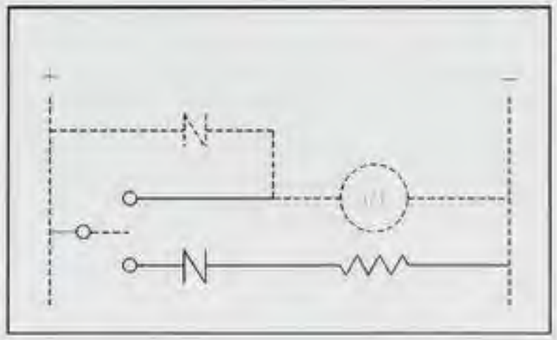
When the steel balls move up to the top of the fiberglass chamber they close the snap switch. This creates a closed circuit through the relay coil and the coil becomes energized.



Once the relay coil is energized the two normally open contacts close.



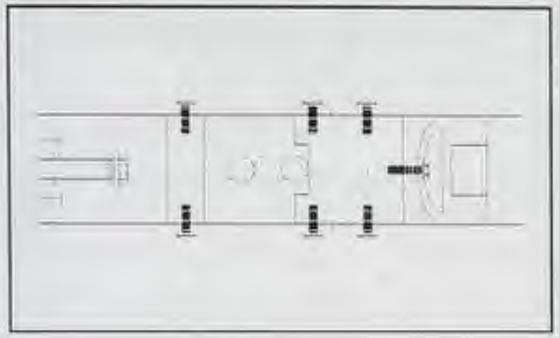
When the top contact closes, it creates a secondary path of power to the relay coil.



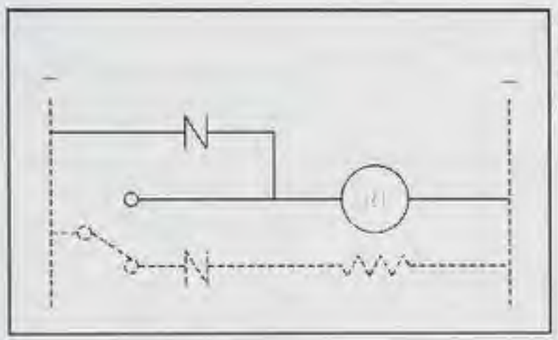
This way, from this point on, no matter what position the snap switch is in, the relay coil will remain energized and latched.



For a very short time after the rocket reaches apogee, the rocket and everything in it is weightless.



At this point, the potential energy in the snap switch, even though it's very small, is enough to push back the steel balls and open the switch.



When the snap switch opens, a path to the ejection piston is created and the ejection piston fires. This pushes out the nosecone along with the parachute and parachute rigging.



INSTRUCTIONS 01

Purchase the following part:
- One 6" length of 3" diameter black delrin rod.

This piece of plastic will be used to make the apogee detector and the parachute piston disc.

MATERIALS 3" Diameter delrin rod 6" long.

WHY? Delrin is an inexpensive black thermoplastic that is easy to cut and machine. It is sturdy enough to act as the rocket body coupler and parachute anchor.

WEB www.mcmaster.com part number 9986K16.

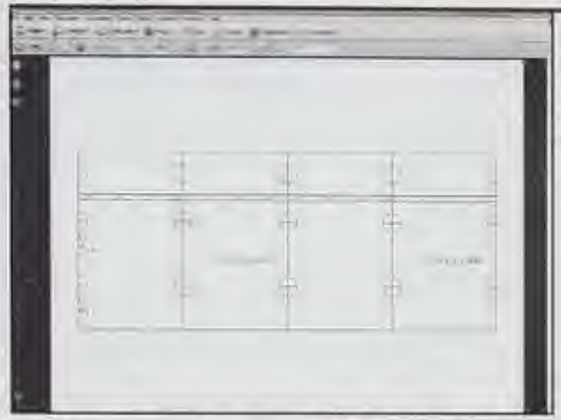


INSTRUCTIONS 02

Using a ruler, draw a line parallel to the rod with a silver *Sharpie* marker. There is usually a seam somewhere on the rod from the manufacturing process; this is a good guide to make sure you get the line parallel to the rod. A carpenter's square can be used in place of a ruler to ensure the line is parallel.

MATERIALS Silver *Sharpie* marker or similar permanent marker.

WHY? Just like constructing the rocket body, a center line is important to keep all the parts of the rocket lined up properly.



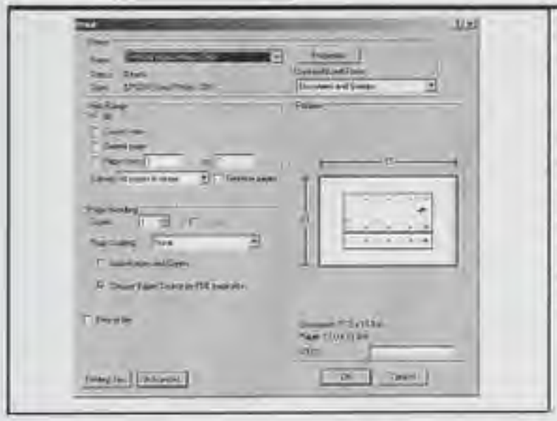
INSTRUCTIONS 03

Download and print out the following template:
- *Bulkhead Bolt Template 8.5 x 11.*

MATERIALS Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 04

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



05 INSTRUCTIONS

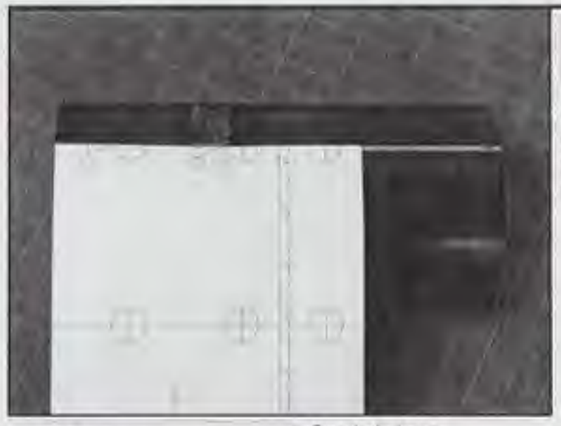
Cut out the Bulkhead Bolt Template as accurately as possible.





MATERIALS

Razor blade or scissors.
Straight edge ruler.



06 INSTRUCTIONS

It's important that the center line on the template, marked with a CL, lines up with the center line on the rod. Once the template is in position, tape the template to the rod.

MATERIALS

Scotch tape.

WHY?

Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly on the apogee detector.



07 INSTRUCTIONS

Fold the template around the rod and tape it together. Make sure the lines on either edge of the template line up with each other.
Tape over each circle on the template and along the edge where the two ends of the template meet.
Finally, tape the top of the template to the rod.

MATERIALS

Scotch tape.

WHY?

It is very important that when you wrap the template around the rod, the lines on either edge of the template line up with each other. This will ensure that all the holes are parallel with the rod and in the correct location.

WHY?

The circles on the template need to be taped so that when the template is drilled the paper won't rip.



08 INSTRUCTIONS

Put the rod in a bench press vise on a drill press. Use a carpenter's square to make sure that the holes on the template are perpendicular to the base.

OPTIONS

Using a hand held drill for this step would be difficult but not impossible.

WHY?

The holes need to be perpendicular to the edge of the rod so that the threaded inserts and bolts will line up properly.



INSTRUCTIONS 09

Drill all twelve holes on the template with a 7/16" drill bit. Drill the holes 3/4" deep.

OPTIONS Using a hand held drill for this step would be difficult but not impossible. If you are not using a drill press with a depth indicator, make sure to mark the drill bit so you don't drill past 3/4".

WHY? The depth of the holes needs to be kept to 3/4" so that they won't intersect other holes drilled in later steps.



INSTRUCTIONS 10

Once all the holes are drilled, the rod should look like this.



INSTRUCTIONS 11

Using an electric miter saw, cut 1" off the top of the rod. Put the 1" piece aside as it will be used for the parachute piston in chapter 6.
Still using an electric miter saw, cut through the rod on the top line of the template.

OPTIONS A hacksaw can be used to cut the rod but you'll probably need an aspirin or two when you're done. DO NOT use a circular saw in place of the electric miter saw. The rod is not long enough to provide ample safety room between your hand and the saw.



INSTRUCTIONS 12

The cut rod should look like this. This picture does not illustrate the 1" cut for the parachute piston.



INSTRUCTIONS 13

Using an electric miter saw, cut the hatched line on the *Bulkhead Bolt Template*. The hatched area is 1/8" thick, the same thickness as most saw blades.

OPTIONS A hacksaw can be used in place of an electric miter saw. However, two cuts will have to be made on this step since the cut is 1/8" thick.

OPTIONS A hacksaw can be used to cut the rod but you'll probably need an aspirin or two when you're done. DO NOT use a circular saw in place of the electric miter saw. The rod is not long enough to provide ample safety room between your hand and the saw.



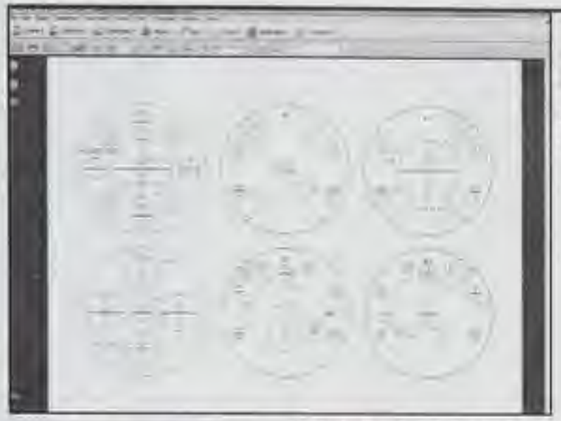
INSTRUCTIONS 14

Using a center punch, make a mark on all four faces of the cut rod next to the center line. This way if you ever loose track where the center line is, it will be easy to find.
Tape the two rod pieces together using scotch tape. I used a blue packing tape because it's a little stronger than scotch tape.
Make sure the center line on both pieces line up with each other. The center line is indicated by an arrow and is marked *CL*.

MATERIALS Scotch tape, packing tape or similar strong tape

OPTIONS A sharp nail can be used in place of the center punch.

WHY? Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 15

Download and print out the following template:
• *Bulkhead Template 8.5 x 11.*

MATERIALS Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 16

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



17 INSTRUCTIONS

Cut out the four round templates marked 1-4. Put aside the templates marked *Piston* and *Nosecone* which will be used in other chapters. Cut the templates out as accurately as possible.



MATERIALS Razor blade or scissors.



18 INSTRUCTIONS

The four templates will be used on the four faces of the plastic rod.
Template #1 will be used on the bottom face.
Template #2 will be used on the bottom middle face.
Template #3 will be used on the top middle face.
Template #4 will be used on the top face.

WHY? It might look complicated and difficult but drilling the holes for the apogee detector is as simple as drilling one hole after another.



19 INSTRUCTIONS

Put template #4 on the top face of the rod. Line up the center line on the round template with the center line on the side of the rod.
The center line on the round template is indicated by an arrow and is marked *CL*.

WHY? Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



20 INSTRUCTIONS

There are four holes marked 3/16" on template #4. Mark each of these holes with a center punch. It is not necessary to mark any other holes yet.
Put the template aside to be used in a later step.



OPTIONS A sharp nail can be used in place of a center punch.



INSTRUCTIONS 21

Drill all four 3/16" holes all the way through both rod pieces.

OPTIONS This will be a tough one to do without a drill press. The holes need to be drilled through 3" of rod and they need to be drilled perpendicular to the face of the rod.

WHY? These four holes will hold bolts that keep the apogee detector together. The holes must be drilled perpendicular to the face of the rod so that the two pieces of rod will not come out skewed.



INSTRUCTIONS 22

Purchase the following part:

- Four 10-32 x 1 1/2" steel machine screws.

MATERIALS Four 10-32 x 1 1/2" fully threaded steel machine screws with philips pan heads.

OPTIONS Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost.

WEB www.mcmaster.com part number 90272A836.



INSTRUCTIONS 23

Put the four 10-32 x 1 1/2" steel machine screws through the four 3/16" holes in the top section of the apogee detector.

WHY? During the next few steps, the two pieces of the apogee detector will be held together without the template or tape in place. The four 10-32 x 1 1/2" machine screws will keep the two rod pieces together.



INSTRUCTIONS 24

Remove the tape holding the two pieces of rod together as well as the template. Make sure the center line on both pieces of rod line up with each other.



INSTRUCTIONS 25

Using a belt sander, sand down the sides of the rod evenly so that it slips into the upper rocket body with a minimal amount of resistance.
The rod shouldn't move when put in the rocket body but it shouldn't be excessively hard to pull out either. What you don't want is any lateral play or wiggle when the rod slips into the rocket body.

OPTIONS

A hand held sander or sandpaper can be used in place of a belt sander. Just make sure the rod is sanded down evenly.

WHY?

The cellular ABS pipe used to make the rocket body in chapter 1 was designed for drainage, not rockets. The inside diameter of the pipe varies from batch to batch. Sanding down the rod will make a custom fit for the apogee detector inside the rocket body.



INSTRUCTIONS 26

The sanded rod should slip in snugly into the rocket body. Here you can see I've painted the upper section of the rocket body white.

WHY?

The cellular ABS pipe used to make the rocket body in chapter 1 was designed for drainage, not rockets. The inside diameter of the pipe varies from batch to batch. Sanding down the rod will make a custom fit for the nosecone support inside the upper rocket body.



INSTRUCTIONS 27

Find the punch marks on the top and bottom faces of the rod from step #14. Using a silver *Sharpie* marker, redraw the center line on the side of the rod pieces.
Draw an arrow on the top of the upper piece and the top of the bottom piece to indicate which side is up.

MATERIALS

Silver *Sharpie* or similar permanent marker.

WHY?

The machine screws will be removed and the pieces will be separated in the next step. If the arrows are not drawn on the center line, it will be very easy to loose track of which side is up and which side is down.

WHY?

Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 28

Remove the four 10-32 x 1 1/2" machine screws from the top of the rod and set them aside to be used in a later step.



INSTRUCTIONS 29

Sand down both faces on the top rod section and bottom rod section. Sand them just enough to make them smooth.



OPTIONS A hand held sander or sandpaper can be used in place of a belt sander.

WHY? It's important that the faces of the rod pieces are perpendicular to sides of the rod.



INSTRUCTIONS 30

Place template #1 on the bottom face of the lower section of the rod. Make sure the center line on the template and the center line on the side of the rod line up correctly. The center line on the round template is indicated by an arrow and is marked *CL*.

WHY? Having a center line that all the templates relate to is the eastest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 31

Mark the 17/64" hole on the template with a center punch.



OPTIONS A sharp nail can be used in place of a center punch.



INSTRUCTIONS 32

Using a drill press, drill the 17/64" hole 1" deep.



OPTIONS A hand held drill can be used in place of a drill press. If you are not using a drill press with a depth indicator, make sure to mark the drill bit so you don't drill past 1".

WHY? This hole is going to be the centering guide for the engine bolt. It will ensure that the engine is centered in the rocket body.



INSTRUCTIONS 33

Place template #2 on the top face of the lower section of the rod. Make sure the center line on the template and the center line on the side of the rod line up correctly. The center line on the round template is indicated by an arrow and is marked *CL*.
Use a center punch to mark the 1 3/8" hole on the template.



OPTIONS A sharp nail can be used in place of a center punch.

WHY? Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 34

Using a 1 3/8" forstner bit, drill the 1 3/8" hole 3/8" deep.



OPTIONS A hand held drill can be used in place of a drill press. If you are not using a drill press with a depth indicator, make sure to mark the drill bit so you don't drill past 3/8".

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



INSTRUCTIONS 35

Place template #3 on the bottom face of the upper section of the rod. Make sure the center line on the template and the center line on the side of the rod line up correctly. The center line on the round template is indicated by an arrow and is marked *CL*. Use a center punch to mark the 7/16" hole, the 1/4" holes, the 7/8" hole, the 3/32" hole and the 9/64" hole on the template.



OPTIONS A sharp nail can be used in place of a center punch.

WHY? Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 36

Using a 7/8" forstner bit, drill the 7/8" hole 1/2" deep.
Drill the 7/16" hole, the 1/4" holes, the 3/32" hole and the 9/64" hole all the way through the rod.
The finished bottom face should look like this.



OPTIONS A hand held drill can be used in place of a drill press. If you are not using a drill press with a depth indicator, make sure to mark the drill bit so you don't drill the 7/8" hole past 1/2".

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



INSTRUCTIONS 37

Place template #4 on the top face of the upper section of the rod. Make sure the center line on the template and the center line on the side of the rod line up correctly. The center line on the round template is indicated by an arrow and is marked CL. Use a center punch to mark the center 7/16" hole on the template.

OPTIONS

A sharp nail can be used in place of a center punch.

WHY?

Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly.



INSTRUCTIONS 38

Using a drill press, drill the center 7/16" hole all the way through the rod. The finished top face should look like this.

OPTIONS

A hand held drill can be used in place of a drill press.



INSTRUCTIONS 39

The bottom face of the top section should look like this.



INSTRUCTIONS 40

Purchase the following part:

- Twelve steel press fit threaded inserts 1/4-20 x 15/32".

MATERIALS

Twelve (two packs) steel press fit threaded inserts 1/4-20 x 15/32".

WHY?

Threaded inserts will allow you to bolt and un-bolt the apogee detector numerous times. If the threads were made directly in the plastic rod, the threads wouldn't be as strong and would degrade with each use.

WEB

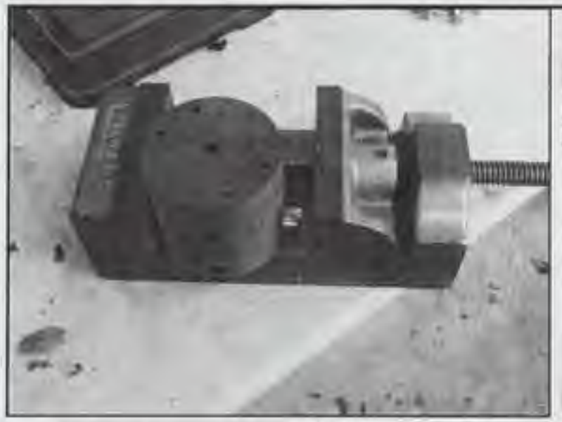
www.mcmaster.com part number 97191A230.



INSTRUCTIONS 41

Put one threaded insert in one of the twelve holes on the side of the apogee detector. You should be able to just get the insert started in the hole.

WHY? Threaded inserts will allow you to bolt and un-bolt the apogee detector numerous times. If the threads were made directly in the plastic rod, the threads wouldn't be as strong and would degrade with each use.



INSTRUCTIONS 42

Using a drill press vise, push the threaded insert the rest of the way into the hole.

OPTIONS A hammer can be used in place of a drill press vise.



INSTRUCTIONS 43

The threaded insert should be flush with the side of the plastic and look like this. Continue to press inserts into all twelve holes on the side of the apogee detector.



INSTRUCTIONS 44

Press two more inserts into the 7/16" holes on the top face of the upper section of the apogee detector.

OPTIONS A hammer can be used in place of a drill press vise.

WHY? One threaded insert on the top face will be used to anchor the 9 volt battery during flight and the other will anchor the parachute piston.



INSTRUCTIONS 45

The apogee detector should now look like this.



INSTRUCTIONS 46

Purchase the following parts:
- 1 Steel u-bolt 1/4-20 x 1 1/2".
- 4 Steel 1/4-20 hex nuts.
- 1 Steel machine screw 1/4-20 x 1 1/2".

MATERIALS

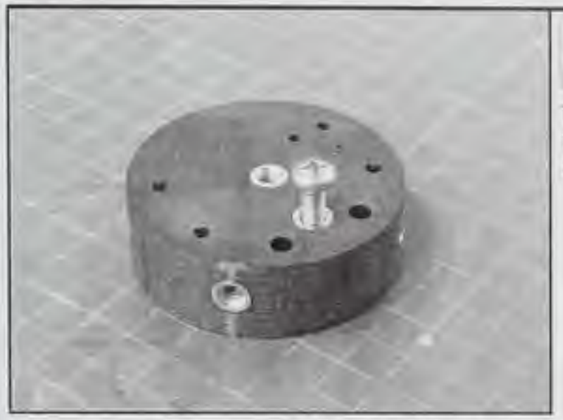
1 Steel u-bolt 1/4-20 x 1 1/2".
4 Steel 1/4-20 hex nuts.
1 Steel pan head philips machine screw 1/4-20 x 1 1/2".

OPTIONS

Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost.

WEB

www.mcmaster.com part number 3043T12.
www.mcmaster.com part number 93827A211.
www.mcmaster.com part number 90272A546.



INSTRUCTIONS 47

Thread the 1/4-20 x 1 1/2" steel machine screw halfway into the threaded insert that is between the two 1/4" holes.

WHY?

The machine screw needs to be installed before the u-bolt because there won't be room once the u-bolt is in place.



INSTRUCTIONS 48

Thread two 1/4-20 hex nuts on the u-bolt. Thread them all the way up to the extent of the threads.



INSTRUCTIONS 49

Insert the u-bolt into the two 1/4" holes on either side of the 1/4-20 x 1 1/2" machine screw. Push the u-bolt through the holes until the 1/4-20 hex nuts rest on the top face.



INSTRUCTIONS 50

Thread two 1/4-20 hex nuts on the bottom of the u-bolt. Stop threading the 1/4-20 hex nuts when they are flush with the bottom of the u-bolt.

WHY? The 9 volt battery is going to be installed below the u-bolt and there won't be any extra room so the bottom of the u-bolt needs to be as close to the bottom face of the upper section as possible.



INSTRUCTIONS 51

Push or pull the u-bolt up so that the 1/4-20 hex nuts on the bottom of the u-bolt are now flush with the bottom face.

WHY? The 9 volt battery is going to be installed below the u-bolt and there won't be any extra room so the bottom of the u-bolt needs to be as close to the bottom face of the upper section as possible.



INSTRUCTIONS 52

Tighten the two 1/4-20 hex nuts on the top of the u-bolt until they are tight against the top face. The parachute will be attached to this u-bolt so make sure the hex nuts are secure.





INSTRUCTIONS 53

Purchase the following part:
- One steel fully threaded stud 1/4-20 x 1".

MATERIALS Steel fully threaded stud 1/4-20 x 1".

OPTIONS Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost.

WEB www.mcmaster.com part number 95475A542.



INSTRUCTIONS 54

Put a drop of *Loctite* 272 thread locking fluid on one end of the 1/4-20 x 1" threaded stud. Insert the stud into the threaded insert in the center of the top face. Screw the stud in about half way, until the bottom of the stud is flush with the bottom of the threaded insert.

MATERIALS *Loctite* 272 thread locker or similar.

WHY? The parachute piston will be anchored to this stud. When the parachute is deployed it has a tendency to spin. The thread locking fluid will prevent the stud from unscrewing and damaging the rocket.

WEB More information about thread locking fluid can be found at www.wikipedia.org under *thread-locking fluid*.



INSTRUCTIONS 55

Purchase the following parts:
- One 10 pole touch safe terminal block.
- One No. 6 x 3/4" sheet metal screw.

MATERIALS 10 Pole touch safe terminal block 0.32" center to center, 0.72" width x 0.68" height.
1 No. 6 x 3/4" philips pan head sheet metal screw.

WHY? For this step we will be using two of the ten poles, the remaining eight will be used in the next chapter. The terminal block in this picture only has eight terminals.

WEB www.mcmaster.com part number 7618K617.
www.mcmaster.com part number 90190A151.



INSTRUCTIONS 56

Using a razor blade, remove two terminals from the terminal strip. Put the remaining eight terminals aside to be used in the next chapter.

MATERIALS Razor blade.

WHY? For this step we will be using two of the ten poles, the remaining eight will be used in the next chapter. The terminal block in this picture only has eight terminals.



INSTRUCTIONS 57

Using a razor blade, remove the small plastic tabs from the bottom of the terminal block. Use a piece of sandpaper to sand down the bottom of the terminal block until it's smooth.

MATERIALS

Razor blade.
120 Grit sandpaper.

WHY?

Double sided tape will stick nicely to the bottom of the terminal block when it is sanded smooth.



INSTRUCTIONS 58

Put a small piece of 1/2" wide double sided tape on the bottom of the terminal block.

MATERIALS

3M Very high bond double sided tape 1/2" width or similar. *

OPTIONS

Silicone adhesive would be a good alternative to double sided tape.

WEB

www.mcmaster.com part number 75935A11.

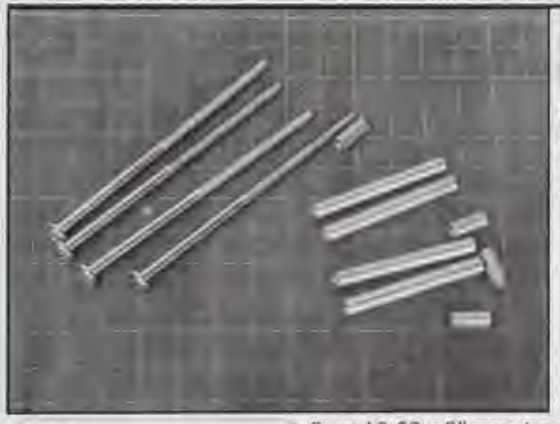


INSTRUCTIONS 59

Put the No. 6 x 3/4" sheet metal screw through the mounting hole on the terminal block until it pierces the double stick tape on the bottom. Remove the backing from the double stick tape and place the terminal block over the 3/32" hole on the top face of the apogee detector. Screw the sheet metal screw firmly into the 3/32" hole so the apogee detector face looks like the picture.

WHY?

This terminal block will be used to connect the parachute piston to the apogee detector. Since the piston needs to be replaced every flight, the terminal block will provide an easy electrical connection point.



INSTRUCTIONS 60

Purchase the following parts:

- Four 10-32 x 3" steel machine screws.
- Four 10-32 x 1/2" aluminum threaded standoffs.
- Four 10-32 x 2" aluminum threaded standoffs.

MATERIALS

Four 10-32 x 3" pan head philips steel machine screws.
Four 10-32 x 1/2" threaded aluminum standoffs.
Four 10-32 x 2" threaded aluminum standoffs.

WHY?

Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost.

WEB

www.mcmaster.com part number 90272A842.
www.mcmaster.com part number 93330A468.
www.mcmaster.com part number 93330A493.



INSTRUCTIONS 61

Put the four 10-32 x 3" steel machine screws through the four 3/16" holes on the bottom section of the apogee detector so that the threads stick out the top face.
The machine screws may or may not easily slide through the holes. If they are tight, just use a philips bit on a cordless drill to screw them through.

WHY? The 10-32 standoffs and machine screws hold the top and bottom of the apogee detector firmly together and provide a space in the middle for the electrical components.



INSTRUCTIONS 62

Thread four 10-32 x 1/2" threaded aluminum standoffs on the 10-32 machine screws. Tighten them down firmly to the face of the apogee detector.

WHY? The 10-32 standoffs and machine screws hold the top and bottom of the apogee detector firmly together and provide a space in the middle for the electrical components.



INSTRUCTIONS 63

Thread four 10-32 x 2" threaded aluminum standoffs on the 10-32 machine screws. Tighten them down firmly.

WHY? The 10-32 standoffs and machine screws hold the top and bottom of the apogee detector firmly together and provide an open space in the middle for the electronic components.



INSTRUCTIONS 64

Take the four 10-32 x 1 1/2" steel machine screws that were put aside in step #28 and install them in the four 3/16" holes on the top face of the upper section of the apogee detector.
The two sections of the apogee detector should now look like this.



INSTRUCTIONS 65

Purchase the following part:
• One 60" length of 1" square fiberglass tubing with 1/8" wall thickness.

MATERIALS Structural fiberglass tube 1" x 1" x 60" - 1/8" wall thickness.

WHY? The fiberglass structural tube will be the chamber that holds the three steel balls that close and open the snap switch at apogee.

WEB www.mcmaster.com part number 8548K21.



INSTRUCTIONS 66

Using a center punch, mark a point near an edge of the fiberglass tube. Mark it in the center of the tube about 1/2" back from the edge. There is a small seam in the center of the tube that is a by-product of the manufacturing process. This can be used as a centering guide.

OPTIONS A sharp nail can be used in place of a center punch.



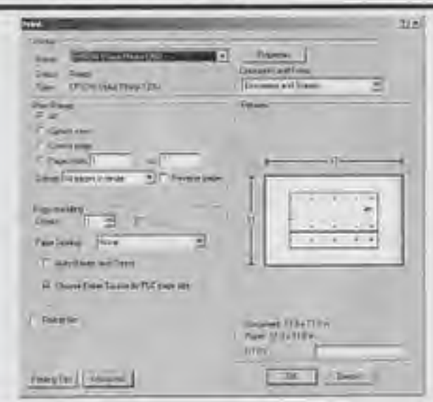
INSTRUCTIONS 67

Download and print out the following template:
• *Safety Pin Template 8.5 x 11.*

MATERIALS Adobe Acrobat reader. Download free at www.adobe.com

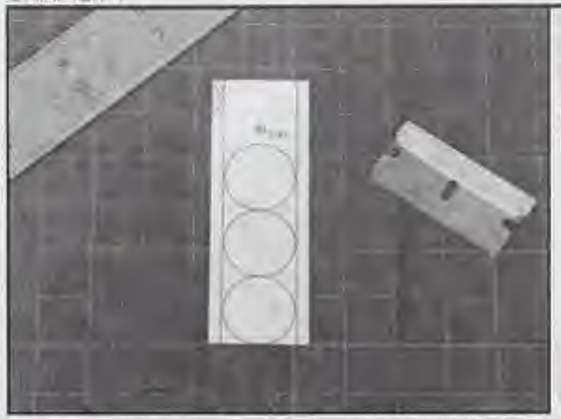
PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 68

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



69 INSTRUCTIONS

Cut out the *Safety Pin Template* as accurately as possible.

MATERIALS Razor blade or scissors. Straight edge ruler.

70 INSTRUCTIONS



Using the punch mark from step #66 as a guide, drill a hole through one side of the fiberglass tube using a 3/4" forstner drill bit.

OPTIONS A hand held drill can be used in place of a drill press.

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



71 INSTRUCTIONS

Using an electric miter saw, cut the fiberglass tube so that the 3/4" hole from the previous step is a half circular hole.

OPTIONS A hacksaw or jigsaw can be used in place of an electric miter saw.

WHY? The snap switch will fit through this half 3/4" half circular hole in the next chapter.

72 INSTRUCTIONS



Take the *Safety Pin Template* and lay it on the fiberglass tube as shown. Make sure the 3/4" half circular hole is on the left and the hatched area of the template is directly above it.

WHY? The safety pin will hold the steel balls in place inside the fiberglass tube when the rocket is not being used. If the steel balls were loose, the snap switch could be damaged.

WHY? The *hatched* section of the template is the section that is filled with small parallel lines.

WHY? The hole for the safety pin is a very small hole that needs to be drilled as accurately as possible. Take your time with this step to make sure the pin is drilled in the correct location.



INSTRUCTIONS 73

Mark the 7/64" hole on the template where the safety pin will go with a center punch.

OPTIONS

A sharp nail can be used in place of the center punch.

WHY?

The hole for the safety pin is a very small hole that needs to be drilled as accurately as possible. Take your time with this step to make sure the pin is drilled in the correct location.

WHY?

The safety pin will hold the steel balls in place inside the fiberglass tube when the racket is not being used. If the steel balls were loose, the snap switch could be damaged.



INSTRUCTIONS 74

Using a silver *Sharpie* marker, mark the fiberglass tube at the bottom of the template.

MATERIALS

Silver *Sharpie* marker or similar permanent marker.

OPTIONS

A razor blade can be used to make a more accurate line.



INSTRUCTIONS 75

Using an electric miter saw, cut the fiberglass tube on the line made in the previous step. The fiberglass tube should measure 1 3/4" in length.

OPTIONS

A hacksaw or jigsaw can be used in place of an electric miter saw.



INSTRUCTIONS 76

Drill the 7/64" hole that was marked in step #73. Drill the hole ALL THE WAY through both fiberglass tube walls.

OPTIONS

A hand held drill can be used in place of a drill press. If doing this step by hand, make sure that the drill is perfectly perpendicular to the fiberglass tube so that both 7/64" holes will be in the correct location.

WHY?

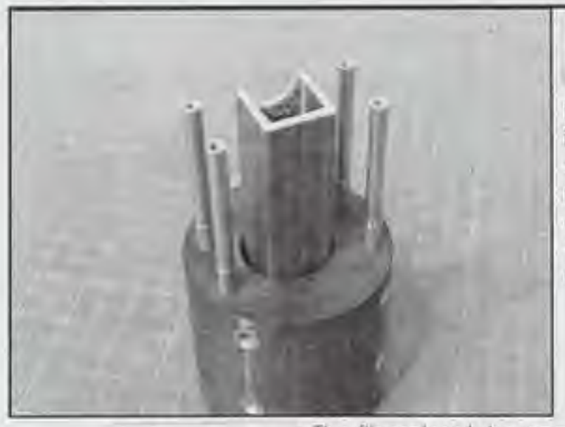
The hole for the safety pin is a very small hole that needs to be drilled as accurately as possible. Take your time with this step to make sure the pin is drilled in the correct location.



INSTRUCTIONS 77

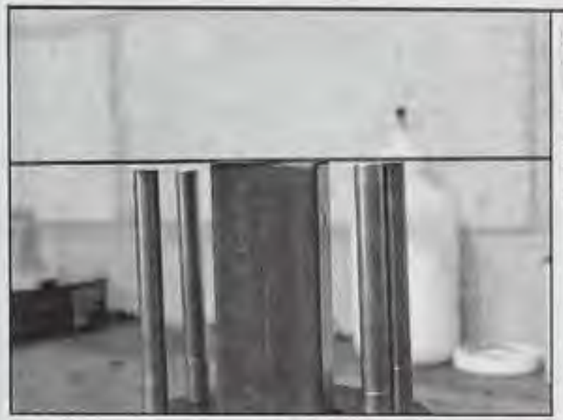
The finished fiberglass tube should look like this.

INSTRUCTIONS 78



Put the fiberglass tube in the 1 3/8" diameter hole in the lower section of the apogee detector. Position the fiberglass tube as shown in the picture. Note the location of the center line on the apogee detector in relation to the fiberglass tube. Also note that the 3/4" half circular hole is on the top.

WHY? The fiberglass tube needs to be positioned correctly in this step as more components will be added in the next chapter.



INSTRUCTIONS 79

Put a ruler on top of the fiberglass tube so that it extends over the 10-32 threaded standoffs. The fiberglass tube will probably be a little higher than the standoffs.

MATERIALS Ruler or straight edge.

WHY? The fiberglass tube needs to be slightly BELOW the level of the 10-32 threaded standoffs so that the upper section of the apogee detector will sit flush on the standoffs.

INSTRUCTIONS 80



Using a belt sander, sand down the BOTTOM of the fiberglass tube. Sand a little bit at a time before going back and checking the height on the apogee detector with a ruler.



OPTIONS A hand sander or sandpaper can be used in place of a belt sander.

WHY? The fiberglass tube needs to be slightly below the level of the 10-32 threaded standoffs so that the upper section of the apogee detector will sit flush on the standoffs.



INSTRUCTIONS 81

The fiberglass tube should look like this when it has been sanded down properly. Just a little bit shorter than the 10-32 threaded standoffs.



INSTRUCTIONS 82

Put the fiberglass tube in the 1 3/8" hole and make sure it is positioned correctly as described in step #78. Put a piece of 1" wide masking tape over the fiberglass tube and down the sides of the apogee detector. Pull the tape tight when putting it over the top of the fiberglass tube so the tube sits firmly inside the 1 3/8" hole. Make sure the fiberglass tube is parallel with the 10-32 threaded standoffs.

MATERIALS Masking tape.

WHY? It's important that the bottom of the fiberglass tube sit tightly against the bottom of the 1 3/8" hole so no epoxy will go under it in the next step.



INSTRUCTIONS 83

Pour two part epoxy AROUND the fiberglass tube in the 1 3/8" hole. The epoxy should not go under the fiberglass tube.
Let the epoxy harden.

MATERIALS
Loctite E-00CL fast setting epoxy.
Loctite applicator gun.
Loctite mixing nozzle.

OPTIONS To reduce costs you can use any two part epoxy. The *Loctite* parts listed just make mixing and applying the epoxy easier.

WEB
www.mcmaster.com part number 6430A16.
www.mcmaster.com part number 74695A71.
www.mcmaster.com part number 74695A12.



INSTRUCTIONS 84

Purchase the following parts:
- Three steel ball bearings 3/4" diameter.
- One steel split ring 1.062" ID.
- One stainless steel cotter pin 3/32" x 2 1/2".

MATERIALS
Three steel ball bearings 3/4" diameter.
One steel split ring 1.062" ID.
One stainless steel cotter pin 3/32" x 2 1/2"

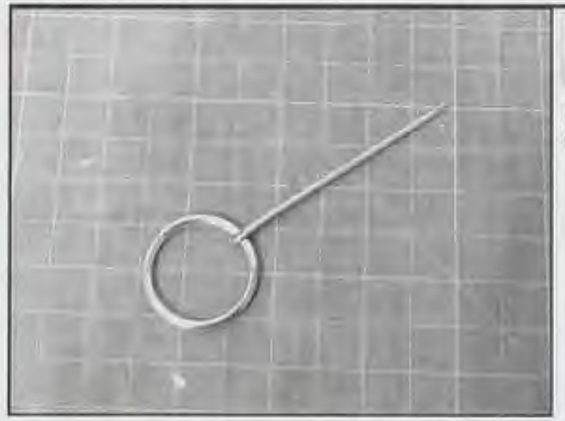
OPTIONS Many McMaster part numbers are for packages of bolts or screws. If only one or two pieces are required and can be purchased individually through another supplier, there would be a considerable savings in the overall project cost.

WEB
www.mcmaster.com part number 96455K59.
www.mcmaster.com part number 86805T38.
www.mcmaster.com part number 98401A449.



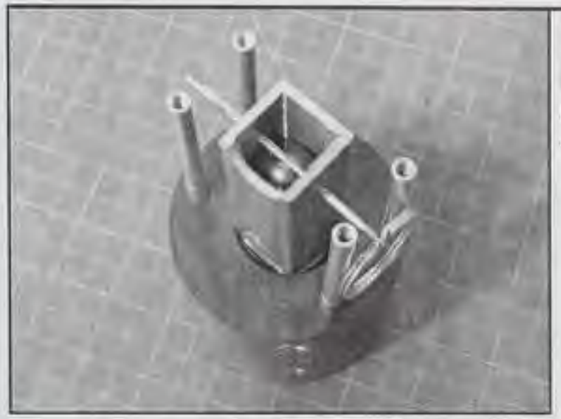
INSTRUCTIONS 85

Once the epoxy has had a chance to harden, place three 3/4" steel balls inside the fiberglass tube.



INSTRUCTIONS 86

Make the safety pin by inserting the 3/32" x 2 1/2" cotter pin on the steel split ring.



INSTRUCTIONS 87

Insert the safety pin through the two 7/64" holes on the fiberglass tube as shown.

WHY? The safety pin will hold the steel balls in place inside the fiberglass tube when the rocket is not being used. If the steel balls were loose, the snap switch could be damaged.



INSTRUCTIONS 88

Install the top section of the apogee detector on the 10-32 threaded standoffs. The u-bolt should be on the OPPOSITE side of the fiberglass tube with the half circular hole. Check the center line. Tighten down the four 10-32 x 1 1/2" machine screws into the 10-32 threaded standoffs.
The mechanical section of the apogee detector is now completed.



CHAPTER 5

MAKING THE APOGEE DETECTOR PART 2

In the last chapter the mechanical portion of the apogee detector was constructed. This chapter will focus on the electrical portion. While it may seem complicated at first, it's just a matter of attaching one wire at a time. The finished product is reliable, robust and just waiting to be launched over and over again.



INSTRUCTIONS 01

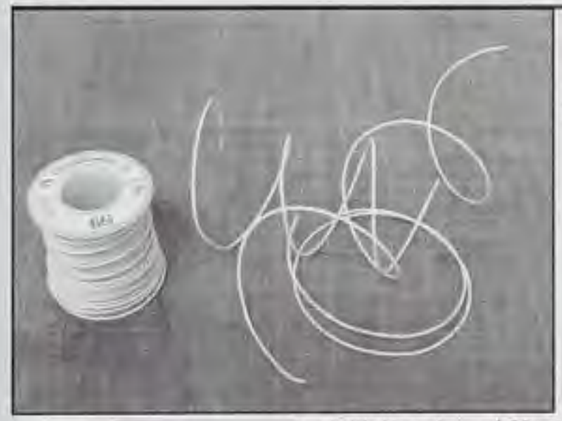
Purchase the following parts:
- Heat shrink tubing 1/4" to 1/8".
- Snap acting SPDT switch with roller lever.
- One roll stranded single conductor wire.

MATERIALS

Heat shrink tubing 1/4" to 1/8".
Subminiature snap acting SPDT switch with roller lever.
One roll stranded single conductor wire 22 AWG - white.

WEB

www.mcmaster.com part number 7496K435.
www.mcmaster.com part number 7193K2.
www.mcmaster.com part number 7587K325.



INSTRUCTIONS 02

Cut three 18" lengths of 22 gauge stranded wire.

WHY?

Multiple colors of 22 gauge stranded wire could have been used in this chapter to make wiring clearer but this would have added additional cost to the project. So I opted to use one roll of white wire and mark it with a black marker where necessary.



INSTRUCTIONS 03

Mark the three wires with a black *Sharpie* marker. Mark one with one dash, another with two dashes and the third with three dashes. Make the marks about two inches from the end of each wire.

MATERIALS Black *Sharpie* or similar permanent marker.

OPTIONS Masking tape or wrap-on wire markers can be used in place of a permanent marker.

WHY? The snap switch will be imbedded in epoxy and unless the wires are marked, it will be difficult to know which wire goes to which part of the switch.



INSTRUCTIONS 04

Strip 1/2" insulation from the end of each wire and set the wires aside.



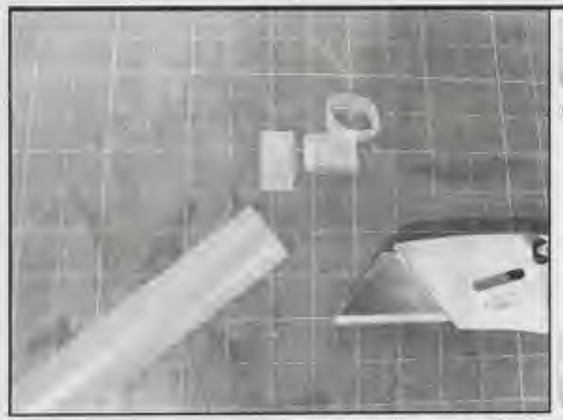
INSTRUCTIONS 05

Purchase the following part:
• Heat shrink tubing 1/2" to 1/4".

MATERIALS Heat shrink tubing, any color, 1/2" to 1/4".

WHY? The hinge on the snap switch is prone to cracking under the stress of the steel balls hitting it when the rocket starts to decelerate. Heat shrink tubing will be used to reinforce this area.

WEB www.mcmaster.com part number 7478K94.



INSTRUCTIONS 06

Cut three 3/8" lengths of heat shrink tubing.

MATERIALS Razor blade or scissors.



INSTRUCTIONS 07

Put a 3/8" loop of heat shrink tubing over the end of the snap switch where the roller lever hinges on the plastic body. Use a heat gun to shrink the tubing so it sits tightly around the switch.
Make sure the heat shrink tubing does not overlap the roller lever which could prevent it from operating properly.



OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The hinge on the snap switch is prone to cracking under the stress of the steel balls hitting it when the rocket starts to decelerate. Heat shrink tubing will be used to reinforce this area.



INSTRUCTIONS 08

Repeat step #7 with the two remaining 3/8" pieces of heat shrink tubing.



OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The hinge on the snap switch is prone to cracking under the stress of the steel balls hitting it when the rocket starts to decelerate. Heat shrink tubing will be used to reinforce this area.



INSTRUCTIONS 09

Run a razor blade around the solder lug on the bottom of the snap switch that was covered with three layers of heat shrink tubing. Remove the heat shrink tubing covering the solder lug.



MATERIALS Razor blade or scissors.

WHY? The solder lug on the snap switch needs to be accessible so a wire can be soldered to it.



INSTRUCTIONS 10

GENTLY place the snap switch in a drill press vise. Make sure the solder lugs are facing up.

OPTIONS Anything can be used to hold the snap switch in place as long as it's secure.



11 INSTRUCTIONS

Solder the wire with one black mark to the common lug on the snap switch. The common lug is the one marked with a C.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.

WEB More information about snap switch operation and wiring can be found at www.wikipedia.org under *miniature snap-action switch*.



12 INSTRUCTIONS

Solder the wire with two black marks to the normally open lug on the snap switch. The normally open lug is the one marked with an *NO*.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



13 INSTRUCTIONS

Solder the wire with three black marks to the normally closed lug on the snap switch. The normally closed lug is the one marked with an *NC*.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



14 INSTRUCTIONS

Bend the normally open and normally closed wires so they are parallel with the Common wire on the snap switch.

WHY? The three switch wires need to be bundled together and sealed in heat shrink tubing so they won't get damaged.



INSTRUCTIONS 15

Bend the three wires so they run down the side of the snap switch.

WHY? The three switch wires need to be bundled together and sealed in heat shrink tubing so they won't get damaged.



INSTRUCTIONS 16

Cut a 1 1/2" length of 1/4" heat shrink tubing.

MATERIALS Razor blades or scissors.

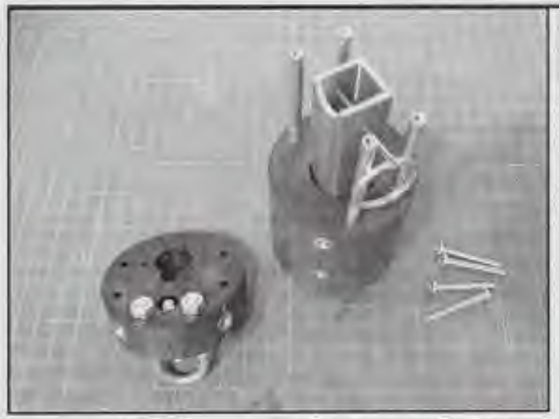


INSTRUCTIONS 17

Using a heat gun, shrink the 1/4" heat shrink tubing around the three wires on the snap switch. Bend the wires at a 90 degree angle before the heat shrink tubing cools.

OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The three switch wires need to be bundled together and sealed in heat shrink tubing so they won't get damaged.



INSTRUCTIONS 18

Take the apogee detector that was completed in the last chapter and remove the four 10-32 x 1 1/2" machine screws that hold the upper section on to the threaded standoffs. Put the lower section and the machine screws aside for now.

WHY? The snap switch needs to be securely fastened in the upper section of the apogee detector. Encasing it in epoxy will ensure a permanent fit.



INSTRUCTIONS 19

Put the upper section of the apogee detector in a drill press vise. Put the u-bolt on the top face into the vise so the bottom face is up and level.

OPTIONS Anything can be used to hold the upper section of the apogee detector as long as it's secure and level.

WHY? Make sure the upper section of the apogee detector is level so the epoxy will be even when it hardens.



INSTRUCTIONS 20

Put a small amount of hot melt glue into the 7/8" x 1/2" hole on the bottom face of the apogee detector. Immediately put the snap switch into the hot glue. Make sure the roller lever is facing up and the roller is centered in the 7/16" hole. Also make sure the back of the snap switch is backed up against the wall of the 7/8" hole. Use the picture for reference.

MATERIALS Hot melt glue gun and glue.

OPTIONS Epoxy can be used in place of the hot melt glue but the snap switch will have to be anchored in place until the epoxy hardens.

WHY? Hot melt glue is a simple and effective way to get the switch to stay in place while the epoxy hardens.



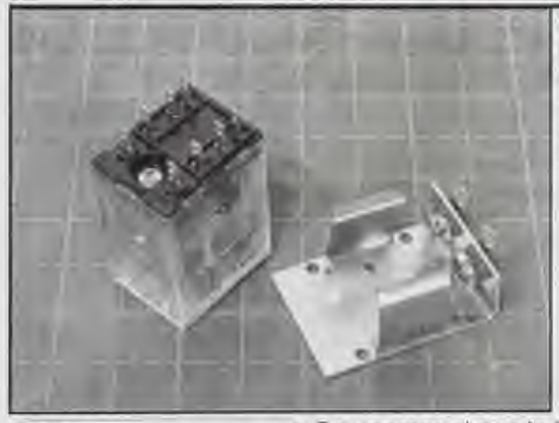
INSTRUCTIONS 21

Fill the 7/8"and 7/16" hole with two part epoxy. Only fill to the hole level with the top of the snap switch body. If you overfill the hole, the roller lever will be epoxied in place and the switch will not function.
Test the switch after the epoxy has hardened to make sure it still works properly.

MATERIALS *Loctite* E-00CL fast setting epoxy.
Loctite applicator gun.
Loctite mixing nozzle.

OPTIONS A less expensive two part epoxy can definetly be substituted for the epoxy in this step. The gun and mixing nozzle just make it easier.

WEB www.mcmaster.com part number 6430A16.
www.mcmaster.com part number 74695A71
www.mcmaster.com part number 74695A12.



INSTRUCTIONS 22

Purchase the following parts:
- One compact spade terminal relay.
- One 9 volt snap in battery holder.

MATERIALS One compact spade terminal relay 12 volts DC DPDT.
One 9 volt snap in battery holder.

WEB www.mcmaster.com part number 69585K87.
www.mcmaster.com part number 7712K62.



23 INSTRUCTIONS

Take the terminal block that was left over from the previous chapter and remove one of the terminals so you are left with seven.

MATERIALS

Razor blade.

24 INSTRUCTIONS

Using a razor blade, remove the small plastic tabs off the bottom of the terminal blocks. Use a piece of sandpaper to sand down the bottom of the terminal block until it's smooth.



MATERIALS

Razor blade.
120 Grit sandpaper.

WHY?

Double sided tape will stick nicely to the bottom of the terminal block when it is sanded smooth.



25 INSTRUCTIONS

Put a small piece of 1/2" wide double sided tape on the bottom of the terminal block.

MATERIALS

3M Very high bond double sided tape 1/2" width or similar.

OPTIONS

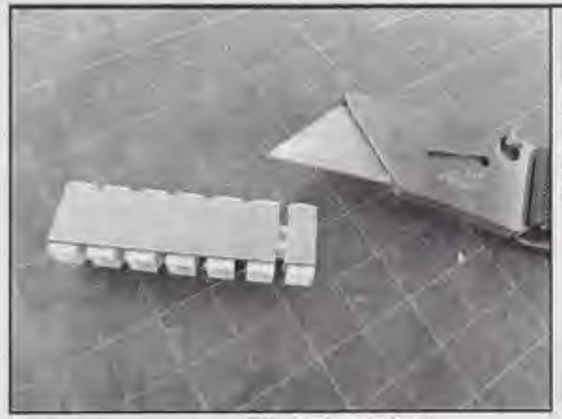
Silicone adhesive would be a good alternative to double sided tape.

WEB

www.mcmaster.com part number 75935A11.

26 INSTRUCTIONS

Using a razor blade, remove the double sided tape from the back of the terminal block where it covers the screw hole between the first and second set of terminals.



MATERIALS

Razor blade.

WHY?

The safety pin that holds the steel balls in place until the rocket is ready to launch will go through this hole so it needs to be clear.



27

INSTRUCTIONS

Put two small pieces of 1/2" wide double sided tape on the back of the 9 volt battery holder.

MATERIALS

3M Very high bond double sided tape 1/2" width or similar.

OPTIONS

Silicone adhesive would be a good alternative to double sided tape.

WEB

www.mcmaster.com part number 75935A11.



28

INSTRUCTIONS

There is a small plastic button on the top of the spade terminal relay. This button is used to manually close or open the relay contacts. Since we won't be using this function and because the relay will be sitting upside down, the button will needs to be removed.
Use a razor blade to cut off the plastic button so it's flush with the top of the relay.

MATERIALS

Razor blade.

WHY?

The relay needs to sit upside down so a flat surface is important.



29

INSTRUCTIONS

Put two small pieces of 1/2" wide double sided tape on the back of the relay.

MATERIALS

3M Very high bond double sided tape 1/2" width or similar.

OPTIONS

Silicone adhesive would be a good alternative to double sided tape.

WEB

www.mcmaster.com part number 75935A11.



30

INSTRUCTIONS

GENTLY put the relay in a drill press vise. Position the relay in the vise so the terminals for the coil of the relay are on the right.

OPTIONS

Anything can be used to hold the relay as long as it's secure.

WEB

Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.

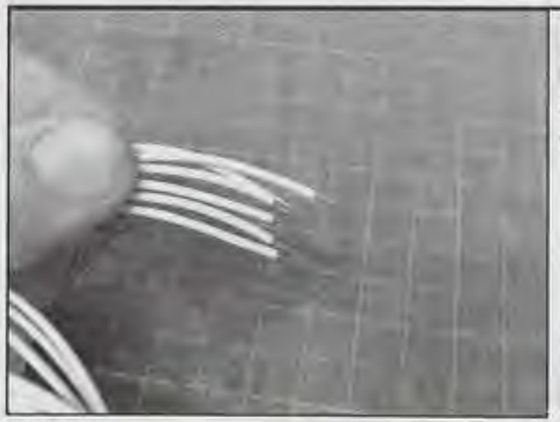


INSTRUCTIONS 31

Cut six 18" lengths of 22 gauge stranded wire.

WHY? Multiple colors of 22 gauge stranded wire could have been used in this chapter to make wiring clearer but this would have added additional cost to the project. So I opted to use only one roll of white wire and mark it with a black marker where necessary.

OPTIONS Masking tape or wrap-on wire markers can be used in place of a permanent marker.



INSTRUCTIONS 32

Strip 1/2" insulation from the end of each wire and set the wires aside.



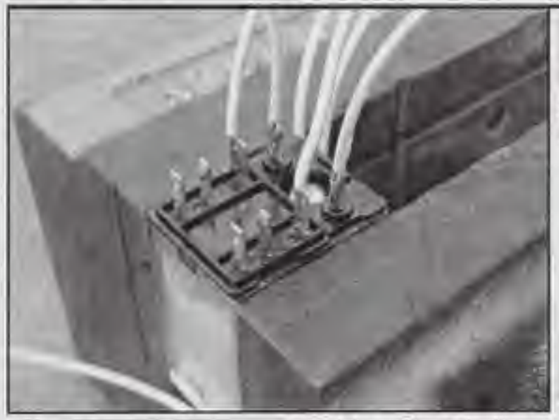
INSTRUCTIONS 33

Solder one 22 gauge stranded wire to each of the two coil terminals on the relay.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.

WEB More information about relays can be found at www.wikipedia.org under *relay / pole and throw*.



INSTRUCTIONS 34

Solder one 22 gauge stranded wire to each of the two common terminals on the relay.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.

WEB More information about relays can be found at www.wikipedia.org under *relay / pole and throw*.



INSTRUCTIONS 35

Solder one 22 gauge stranded wire to each of the two normally open terminals on the relay.

MATERIALS

Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.

WEB More information about relays can be found at www.wikipedia.org under *relay / pole and throw*.



INSTRUCTIONS 36

Purchase the following part:
- Heat shrink tubing 1/8" to 1/16".

MATERIALS

Heat shrink tubing 1/8" to 1/16".

WHY? Putting a small piece of heat shrink tubing on the relay terminals will prevent anything from shorting across the terminals.

WEB www.mcmaster.com part number 7856K631.



INSTRUCTIONS 37

Cut six 1/2" lengths of 1/8" heat shrink tubing.

MATERIALS

Razor blade or scissors.

WHY? Putting a small piece of heat shrink tubing on the relay terminals will prevent anything from shorting across the terminals.



INSTRUCTIONS 38

Using a heat gun, shrink the heat shrink tubing around each of the six soldered relay terminals.

OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.



INSTRUCTIONS 39

Cut four 18" lengths of 22 gauge stranded wire.

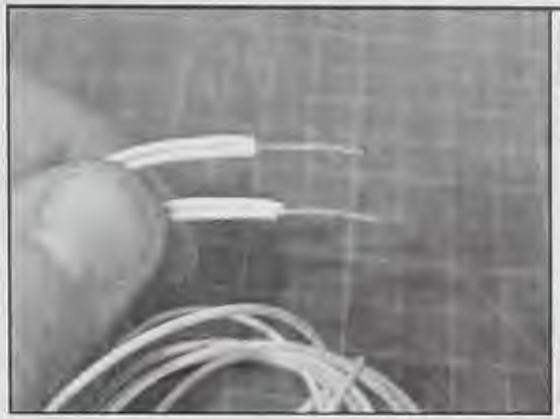
WHY? Multiple colors of 22 gauge stranded wire could have been used in this chapter to make wiring clearer but this would have added additional cost to the project. So I opted to use only one roll of white wire and mark it with a black marker where necessary.



INSTRUCTIONS 40

Strip 3/4" of insulation from the end of each wire.

WHY? There needs to be two positive and two negative leads coming off the 9 volt battery holder.



INSTRUCTIONS 41

Twist two of the wires together, repeat with the remaining two wires.



INSTRUCTIONS 42

Solder the twisted pair of wires together. Repeat with the remaining twisted pair.

MATERIALS Solder with rosin flux core.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



INSTRUCTIONS 43

Place the 9 volt battery holder in a drill press vise.

OPTIONS

Anything can be used to hold the 9 volt battery holder in place as long as it's secure.



INSTRUCTIONS 44

Trim the two pairs of 22 gauge wire from step #42 so that the soldered ends are about 1/4" long.



INSTRUCTIONS 45

Solder the first twisted pair of wires to the negative terminal of the 9 volt battery holder. Solder them so that they are perpendicular to the battery holder and going away from it to the left. Use the picture for reference.

MATERIALS

Solder with rosin flux core.

WEB

Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



INSTRUCTIONS 46

Solder the second twisted pair of wires to the positive terminal of the 9 volt battery holder. Solder them so that they are perpendicular to the battery holder and going away from it to the left. Use the picture for reference.

MATERIALS

Solder with rosin flux core.

WEB

Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



INSTRUCTIONS 47

Mark the two wires that are soldered to the positive terminal on the battery holder with two black marks. Mark the wires a few inches from the end of the wire.

MATERIALS Black *Sharpie* or similar permanent marker.

OPTIONS Masking tape or wrap-on wire markers can be used in place of a permanent marker.

WHY? The battery wires will be run with several other wires and unless the wires are marked, it will be difficult to know which wire goes to which terminal.



INSTRUCTIONS 48

Mark the two wires that are soldered to the negative terminal on the battery holder with one black mark. Mark the wires a few inches from the end of the wire.

MATERIALS Black *Sharpie* or similar permanent marker.

OPTIONS Masking tape or wrap-on wire markers can be used in place of a permanent marker.

WHY? The battery wires will be run with several other wires and unless the wires are marked, it will be difficult to know which wire goes to which terminal.



INSTRUCTIONS 49

Cut a 1" length of 1/8" heat shrink tubing.

MATERIALS Razor blade or scissors.



INSTRUCTIONS 50

Install and shrink the 1" length of 1/8" heat shrink tubing on the wires that are attached to the positive terminal of the battery holder.

OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.



INSTRUCTIONS 51

Cut a 1/2" length of 1/4" heat shrink tubing.

MATERIALS

Razor blade or scissors.



INSTRUCTIONS 53

Remove the paper backing from the double sided tape on the back of the battery holder and install it on the square fiberglass tube. Make sure the battery holder is centered on the side of the square fiberglass tube and flush with the plastic face of the apogee detector.
The battery holder should be on the side of the square tube OPPOSITE the half circular hole.

WHY?

The 1/4-20 x 1 1/2" machine screw that is between the u-bolt on the upper section of the apogee detector will be used to hold the battery in place during flight. Putting the battery holder on the correct side is important.



INSTRUCTIONS 52

Install and shrink the 1/2" length of 1/4" heat shrink tubing over all four wires that are attached to the battery holder. The 1/4" heat shrink tubing should overlap the 1/8" heat shrink tubing about 1/2".

OPTIONS

A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.



INSTRUCTIONS 54

Remove the paper backing from the double sided tape on the back of the DPDT relay and install it on the square fiberglass tube. Make sure the DPDT relay is centered on the side of the square fiberglass tube and flush with the plastic face of the apogee detector.
The DPDT relay should be on the SAME side of the square tube the half circular hole.



INSTRUCTIONS 55

Remove the paper backing from the double sided tape on the back of the terminal block. Position the terminal block so the mounting hole is towards the top.



INSTRUCTIONS 56

Line up the mounting hole on the top of the terminal block with the end of the safety pin. Push the terminal block towards the square fiberglass tube, sliding it on the safety pin.

WHY? The safety pin holds the steel balls in place until the rocket is ready to launch.



INSTRUCTIONS 57

Attach the terminal block to the square fiberglass tube so that the safety pin and the mounting hole on the terminal block are lined up. The safety pin should slide in and out of the fiberglass tube easily.

WHY? The safety pin holds the steel balls in place until the rocket is ready to launch.



INSTRUCTIONS 58

Cut two 18" lengths of 22 gauge stranded wire.

WHY? Multiple colors of 22 gauge stranded wire could have been used in this chapter to make wiring clearer but this would have added additional cost to the project. So I opted to use only one roll of white wire and mark it with a black marker where necessary.



INSTRUCTIONS 59

Strip 1/2" insulation from the end of each wire.





INSTRUCTIONS 60

Attach the two stripped wire ends to the two terminals on the top section of the apogee detector.

WHY? This terminal block will be used to connect the parachute piston to the apogee detector. Since the piston needs to be replaced every flight, the terminal block will provide an easy electrical connection point.

WHY? Don't over-tighten the terminal block lugs, tighten them just until the screws are snug. Over-tightening the lugs can break the wire strands and lead to a malfunction.



INSTRUCTIONS 61

Feed the two 22 guage wires down through the 9/64" hole on the top face of the apogee detector.



INSTRUCTIONS 62

Attach the top section of the apogee detector to the bottom section with the four 1/4-20 x 1 1/2" machine screws that were removed in step #18. The snap switch wires should be directly over the relay and the u-bolt should be over the battery holder. Pay special attention to the wires on both the upper and lower sections to prevent pinching as the two pieces come together.



INSTRUCTIONS 63

The three wire bundle from the snap switch should fit nicely between the six terminals of the relay.



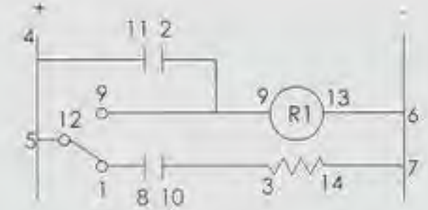
INSTRUCTIONS 64

I know it looks like there's a million wires spilling out the side of the apogee detector and they're all the same color and you have no idea where they go.
DON'T FREAK OUT!
Wiring the apogee detector is as simple as attaching one wire to the terminal block then another. Before you know it you'll be done.

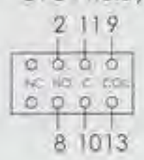
APOGEE DETECTOR CIRCUIT

Terminal Block

Normally Closed Switch Contact 1	1	8 Normally Open Relay Contact
Normally Open Relay Contact 2	2	9 Normally Open Switch Contact / Relay Coil - Two Wires
Ejection Piston 3	3	10 Common Relay Contact
9 Volt Possitive 4	4	11 Common Relay Contact
9 Volt Possitive 5	5	12 Common Switch Contact
9 Volt Negative 6	6	13 Relay Coil
9 Volt Negative 7	7	14 Ejection Piston



DPDT Relay



Switch Wire Legend

I	Common
II	Normally Open
III	Normally Closed

Battery Wire Legend

I	Negative
II	Positive



INSTRUCTIONS 65

Find the two wires from the negative terminal on the battery holder, they are the ones marked with one black mark on each wire.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the wires from the positive terminal on the battery holder are marked with two black marks and the ones from the negative terminal are marked with one black mark.



INSTRUCTIONS 66

Cut the two wires with enough room to reach terminals 6 and 7 on the terminal block. Strip 1/4" insulation from both wires and attach one to terminal 6 and one to terminal 7.
It is not important which negative wire goes to which terminal.
Refer to the wiring diagram after step #64 for a detailed drawing.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the wires from the positive terminal on the battery holder are marked with two black marks and the ones from the negative terminal are marked with one black mark.



INSTRUCTIONS 67

Find the two wires from the positive terminal on the battery holder, they are the ones marked with two black marks on each wire.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the wires from the positive terminal on the battery holder are marked with two black marks and the ones from the negative terminal are marked with one black mark.



INSTRUCTIONS 68

Cut the two wires with enough room to reach terminals 4 and 5 on the terminal block. Strip 1/4" insulation from both wires and attach one to terminal 4 and one to terminal 5.
It is not important which positive wire goes to which terminal.
Refer to the wiring diagram after step #64 for a detailed drawing.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the wires from the positive terminal on the battery holder are marked with two black marks and the ones from the negative terminal are marked with one black mark.



INSTRUCTIONS 69

Find one wire from the ejection piston terminal block on the top face of the apogee detector. Cut the wire with enough room to reach terminal 3 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 3.
It is not important which of the two wires from the ejection piston terminal goes to terminal 3.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 70

Find the wire from the normally open relay contact closest to the fiberglass tube.
Cut the wire with enough room to reach terminal 2 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 2.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 71

Find the wire from the normally closed switch contact. This is the wire from the snap switch with three black marks.
Cut the wire with enough room to reach terminal 1 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 1.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the three wires from the snap switch are marked one black mark for the common, two black marks for the normally open contact and three black marks for the normally closed contact.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 72

Find the wire from the normally open relay contact farthest from the fiberglass tube.
Cut the wire with enough room to reach terminal 8 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 8.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 73

Find the wire from the normally open switch contact. This is the wire from the snap switch with two black marks.
Also find the relay coil contact closest to the fiberglass tube.
Cut the wires with enough room to reach terminal 9 on the terminal block. Strip 1/4" insulation from the wires.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the three wires from the snap switch are marked one black mark for the common, two black marks for the normally open contact and three black marks for the normally closed contact.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 74

Twist both wires together and put a small amount of solder on the wires, just enough to bond them together.

WHY? A small amount of solder on the wires will prevent the wires from separating in the terminal block. This could cause a failure of the apogee detector.

WEB Many articles and tutorials on basic soldering techniques are available online. Search Google, YouTube and Wikipedia.



INSTRUCTIONS 75

Attach both wires to terminal 9.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 76

Find the wire from the common relay contact farthest from the fiberglass tube.
Cut the wire with enough room to reach terminal 10 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 10.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 77

Find the wire from the common relay contact closest to the fiberglass tube.
Cut the wire with enough room to reach terminal 11 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 11.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 78

Find the wire from the common switch contact. This is the wire from the snap switch with one black mark.
Cut the wire with enough room to reach terminal 12 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 12.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Remember the three wires from the snap switch are marked one black mark for the common, two black marks for the normally open contact and three black marks for the normally closed contact.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.

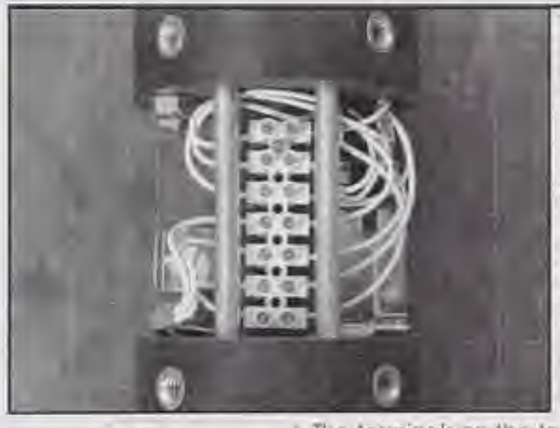


INSTRUCTIONS 79

Find the relay coil contact furthest from the fiberglass tube.
Cut the wire with enough room to reach terminal 13 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 13.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



INSTRUCTIONS 80

Find the second wire from the ejection piston terminal block on the top face of the apogee detector.
Cut the wire with enough room to reach terminal 14 on the terminal block. Strip 1/4" insulation from the wire and attach the wire to terminal 14.
It is not important which of the two wires from the ejection piston terminal goes to terminal 14.

WHY? The terminals on the terminal block are numbered starting with number one at the top left and working down to number seven. Then number eight on the top right working down to number fourteen.

WHY? Refer to the wiring diagram after step #64 for a detailed drawing.



81

INSTRUCTIONS

Neatly bundle the wires on either side of the terminal block with small zip ties.

MATERIALS

Small zip ties.

WHY?

Zip ties will keep the wires secure and will eliminate the possibility of wires getting pulled out of the terminal block or pinched when the apogee detector is installed in the rocket body.

WEB

www.mcmaster.com part number 7130K52



82

INSTRUCTIONS

Purchase the following part:

- One double loop shaft coupling.

MATERIALS

Double loop shaft coupling 1/4" x 1/4" bore.

WHY?

The shaft coupling will compensate for any alignment issues between the apogee detector and the parachute piston.

WEB

www.mcmaster.com part number 6183K33.



83

INSTRUCTIONS

Install the shaft coupling on the 1/4-20 x 1" threaded stud on the top face of the apogee detector. Tighten the setscrew with a 1/16" hex key.

WHY?

The shaft coupling will compensate for any alignment issues between the apogee detector and the parachute piston.



84

INSTRUCTIONS

To test the apogee detector, attach a 9 to 13 volt DC light bulb to the two open terminals on the terminal block on the top face of the apogee detector. The light bulb will simulate the parachute piston ejection charge.

MATERIALS

9-12 Volt DC light bulb.

OPTIONS

You can test the apogee with a small piece of nichrome wire instead of a bulb if you want. The nichrome wire will glow red hot or burn through depending on the gauge.

WHY?

Testing the apogee detector is crucial in making sure all the parts have been wired correctly.



INSTRUCTIONS 85

Install a 9 volt battery in the battery holder on the side of the apogee detector. You can lower down the 1/4-20 x 1 1/2" screw on the top of the apogee detector to see how it will hold the battery in place.

MATERIALS 9 Volt battery.

WHY? Use a new 9 volt battery. This is important since the relay coil is rated at 12 volts. A new 9 volt battery will work fine but a weak battery might not have enough amperage to energize the coil.



INSTRUCTIONS 86

Pull out the safety pin.

WHY? Removal of the safety pin enables the apogee detector. It is usually removed just prior to flight.



INSTRUCTIONS 87

Turn the apogee detector upside down. This simulates the rocket engine cutting out and the steel balls moving up to the front of the fiberglass tube to close the snap switch.



INSTRUCTIONS 88

Turn the apogee detector right side up. This simulates the rocket at apogee when the rocket and the steel balls will be momentarily weightless and the spring in the snap switch will push the steel balls back. The light bulb should turn on.
The apogee detector is now ready for flight.

WHY? To reset the apogee detector, remove the battery from the battery holder. This removes power from the circuit and releases the relay coil.



CHAPTER 6

MAKING THE PARACHUTE PISTON

With the exception of the plastic piston disc, the parachute piston is a disposable device that converts chemical energy in the form of a simple pyrogen into kinetic energy. The parachute piston activates when the rocket reaches apogee and the apogee detector sends voltage to ignite the pyrogen in the bottom of the piston. The expanding gas forces the piston to stroke out 8" ejecting the parachute. A small o-ring on the shaft of the piston seals the piston and protects the parachute and rigging from hot gasses.



INSTRUCTIONS 01

Purchase the following parts:
- 1" PVC pipe 2' long.
- 1/2" PVC pipe 2' long.
- 1/2" PVC union slip x slip.

MATERIALS
1" Schedule 40 PVC pipe 2' long.
1/2" Schedule 40 PVC pipe 2' long.
1/2" Schedule 40 PVC union slip x slip.

WHY?
Schedule 40 PVC pipe and fittings are readily available, affordable and easy to work with.

WEB
Home Depot part number 193755 or similar.
Home Depot part number 193862 or similar.
Home Depot part number 451132 or similar.



INSTRUCTIONS 02

Purchase the following parts:
- Two 1" PVC caps.
- One 1/2" PVC cap.
- Two 1/2" PVC couplings.

MATERIALS
Two 1" Schedule 40 PVC caps.
One 1/2" Schedule 40 PVC cap.
Two 1/2" Schedule 40 PVC couplings.

WHY?
Schedule 40 PVC pipe and fittings are readily available, affordable and easy to work with.

WEB
Home Depot part number 188182 or similar.
Home Depot part number 188166 or similar.
Home Depot part number 188069 or similar.



03 INSTRUCTIONS

Using PVC glue, attach a 1/2" coupling to a 2' length of 1/2" pipe.

MATERIALS

I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



04 INSTRUCTIONS

Using a black *Sharpie* marker, make two marks on the 1/2" coupling. Each mark should be 1/2" from either edge of the coupling.

MATERIALS

Black *Sharpie* or similar permanent marker.



05 INSTRUCTIONS

Using an electric miter saw, cut 1/2" off the end of the coupling.

OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.

WHY?

This 1/2" piece of coupling will be used as a shim in the next few steps to make sure work on the coupling is square.



06 INSTRUCTIONS

Slip the 1/2" coupling piece on the 1/2" pipe as a shim to make the next cut square.
Cut the 1/2" coupling on the remaining mark.

OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.



INSTRUCTIONS 07

Using a black *Sharpie* marker, mark the 1/2" pipe 10 3/8" down from the outside edge of the coupling that was glued to the pipe.

MATERIALS

Black *Sharpie* or similar permanent marker.



INSTRUCTIONS 08

Cut the 1/2" pipe at 10 3/8" using the piece of 1/2" coupling as a shim to make the cut square.

OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.

WHY?

This piece will form the main piston in the parachute piston assembly.



INSTRUCTIONS 09

Mark a spot on a new length of 1/2" pipe 1 5/8" from the edge.

MATERIALS

Black *Sharpie* or similar permanent marker.

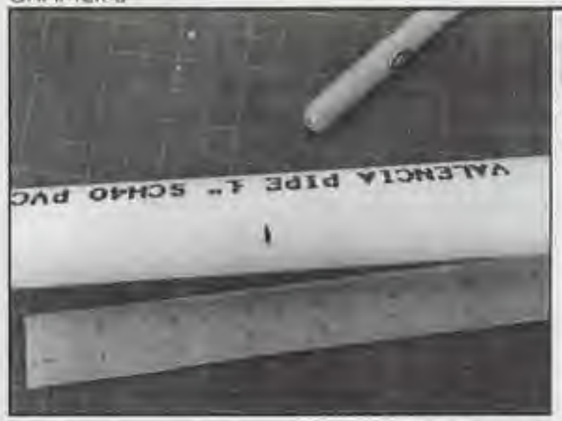


INSTRUCTIONS 10

Cut the 1/2" pipe at the 1 5/8" mark. Set this small piece aside.

OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.



INSTRUCTIONS 11

Mark a spot on a length of 1" pipe 8 3/4" from the edge.

MATERIALS

Black *Sharpie* or similar permanent-marker.



INSTRUCTIONS 12

Cut the 1" pipe at the 8 3/4" mark. Set this piece aside.



OPTIONS

A pipe cutter or a hacksaw can be used in place of an electric miter saw.



INSTRUCTIONS 13

Before starting this step, make sure you read the instructions through step #14.
Using a belt sander and the 1/2" piece of coupling as a shim, sand down the 1/2" coupling attached to the 1/2" pipe.



OPTIONS

A hand sander or sandpaper can be used in place of a belt sander.

WHY?

The 1/2" coupling is going to act as the piston head and needs to slide easily inside a 1" piece of pipe. There will be an o-ring added later that will act as the seal on the piston head.



INSTRUCTIONS 14

The sanded piece of 1/2" coupling should easily slide in the 1" PVC pipe. The inside diameter of the 1" pipe varies a little due to the manufacturing process. Make sure the 1/2" sanded coupling can EASILY slide up and down the 1" pipe.
You don't want a huge amount of room around the coupling but you don't want it to get stuck either.
The purpose of the 1/2" coupling is to guide the piston, NOT TO SEAL IT. An o-ring will be added later to do that.

WHY?

The 1/2" coupling is going to act as the piston head and needs to slide easily inside a 1" piece of pipe. There will be an o-ring added later that will act as the seal on the piston head.



INSTRUCTIONS 15

The three pipe pieces should now look like this. Put the three pipe pieces aside for now.



INSTRUCTIONS 16

There's usually a small circle or nub directly in the center of the PVC caps left over from the manufacturing process. Mark the center of the cap with a center punch on both 1" caps.



OPTIONS A sharp nail can be used in place of a center punch.

WHY? It's important that the holes in the PVC caps are as centered as possible.

WHY? Make sure to mark the center on BOTH of the 1" caps.



INSTRUCTIONS 17

There's usually a small circle or nub directly in the center of the PVC caps left over from the manufacturing process. Mark the center of the 1/2" cap with a center punch.



OPTIONS A sharp nail can be used in place of a center punch.

WHY? It's important that the holes in the PVC caps are as centered as possible.



INSTRUCTIONS 18

Using an electric miter saw, cut a 3" length of 1/2" pipe and a 3" length of 1" pipe. Put the two scrap pieces aside for now.



OPTIONS A pipe cutter or a hacksaw can be used in place of an electric miter saw.

WHY? These two scrap pieces will be used to securely hold the caps in a drill press vise.



INSTRUCTIONS 19

Put a 1/2" cap firmly on the scrap piece of 1/2" pipe and secure the pipe in a drill press vise.
Using the center punch mark as a guide, drill a 1/4" hole in the center of the 1/2" cap.

OPTIONS A cordless drill can be used in place of the drill press as long as the 1/4" hole is drilled accurately.

WHY? This hole will eventually hold a cap screw that will anchor the parachute piston to the top of the apogee detector.



INSTRUCTIONS 20

Put a 1" cap firmly on the scrap piece of 1" pipe and secure the pipe in a drill press vise.
Using the center punch mark as a guide, drill a 1/4" hole in the center of the 1" cap.

OPTIONS A cordless drill can be used in place of the drill press as long as the 1/4" hole is drilled accurately.



INSTRUCTIONS 21

Put a 1" cap firmly on the scrap piece of 1" pipe and secure the pipe in a drill press vise.
Using the center punch mark as a guide, drill a 7/8" hole in the center of the 1" cap using a 7/8" forstner bit.

OPTIONS A cordless drill can be used in place of the drill press as long as the 7/8" hole is drilled accurately.

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



INSTRUCTIONS 22

Purchase the following parts:
- Two 1/4-20 x 7/8" socket cap screws.
- Two 1/4-20 locknuts.
- One o-ring 13/16" ID x 1" OD.

MATERIALS
Two 1/4-20 x 7/8" steel button head socket cap screws.
Two 1/4-20 nylon insert hex locknuts.
One quad cross section o-ring 13/16" ID x 1" OD.

WEB
www.mcmaster.com part number 91255A541.
www.mcmaster.com part number 97135A210.
www.mcmaster.com part number 90025k244.



INSTRUCTIONS 23

Put a 1/4-20 x 7/8" cap screw through each 1/4" hole in the 1" cap and the 1/2" cap.
Tighten two 1/4-20 hex locknuts to the cap screws using a 5/32" hex key and a 7/16" open end box wrench.



OPTIONS Any 1/4-20 x 7/8 Bolts or machine screws can be used in place of the hex head cap screws. I find that the hex head is just easier to install and tighten.

WHY? These two 7/8" screws will be the anchoring points for piston to the apogee detector and the piston disc. Having a locknut on the screws ensures they will remain tight against the caps.



INSTRUCTIONS 24

Glue the 1/2" cap to the 1 5/8" length of 1/2" PVC pipe from step #15.



MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 25

Take the 1/2" PVC union apart. There will be male section, an o-ring and two parts that make up the female section.



INSTRUCTIONS 26

Glue the 1/2" pipe from step #24 to the male section of the PVC union.



MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.

WHY? This section will hold the pyrogen and the igniter.



INSTRUCTIONS 27

Using a variable diameter drill bit, taper one end of the 1" PVC pipe from step #15. This taper will make it much easier to install the piston rod with the o-ring on it. While this step is not necessary it definitely makes assembly easier.

The variable diameter drill bit used in this step will also be used in chapter 9.

MATERIALS Variable diameter drill bit 5/8" to 1-3/16"

WHY? Making a tapered hole on one end of the 1" PVC pipe makes it much easier to slide the o-ring into the pipe. This step is optional and definitely not necessary.

WEB www.mcmaster.com part number 8910A13.



INSTRUCTIONS 28

Slide the 13/16" o-ring over the 1/2" pipe from step #15 until it rests against the coupling. Make sure the o-ring isn't twisted as this will decrease its performance.

WHY? This o-ring will form a tight seal between the outside of the1/2" pipe and the inside of the 1" pipe.



INSTRUCTIONS 29

Take the 1" cap with a 7/8" hole in it and glue it to the 1" pipe.
If you tapered the 1" pipe in step #27, make sure to put the 1" cap on the OPPOSITE end.

MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.

WHY? If you tapered the 1" PVC in step #27, make sure to put the 1" cap on the OPPOSITE end.



INSTRUCTIONS 30

All the main pieces for the piston should now look like this.



INSTRUCTIONS 31

Using a cordless drill, drill a 5/32" hole through ONE side of the 1/2" cap / union assembly. Drill the hole half way up the side of the cap.



INSTRUCTIONS 32

Purchase the following part:
• One small spool of 32 gauge nichrome wire.

Using a pair of wire cutters, cut an 8" length of nichrome wire.

The nichrome wire spool used in this step will also be used in chapter 10.

MATERIALS

Nickel Chromium wire 32 gauge .0.008" diameter, 1/8 lb. spool.

WHY?

Also known as nichrome, nickel chromium is a very temperature resistant wire. It is often used for heating elements, resistance windings and hot wire cutters.

WEB

www.mcmaster.com part numoer 8880K83.



INSTRUCTIONS 33

Purchase the following part:
• One roll stranded single conductor wire.

Cut two 16" lengths of 22 gauge stranded wire.

MATERIALS

One roll stranded single conductor wire 22 AWG - white.

WEB

www.mcmaster.com part number 7587K325.



INSTRUCTIONS 34

Strip 3/4" insulation off the end of each wire.



INSTRUCTIONS 35

Split the strands into a V on one of the 18" wires.

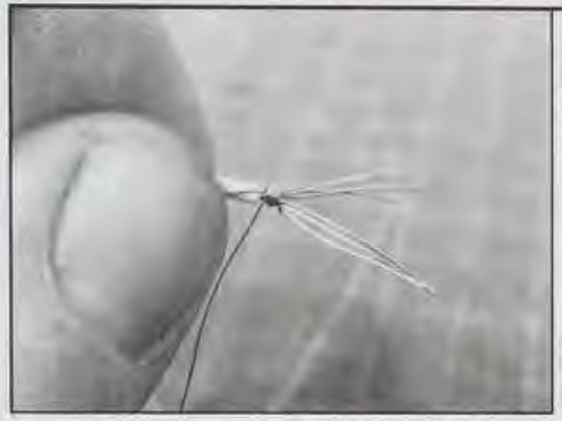
WHY? The nichrome wire will be used to light the pyrogen that will extend the piston at apogee. It's not possible to solder nichrome wire so looping it between strands of 22 gauge wire and then twisting them tight is an excellent way to ensure the igniter works consistently.



INSTRUCTIONS 36

Hold the length of nichrome wire between your thumb and index finger and run it between the split strands of 22 gauge wire.

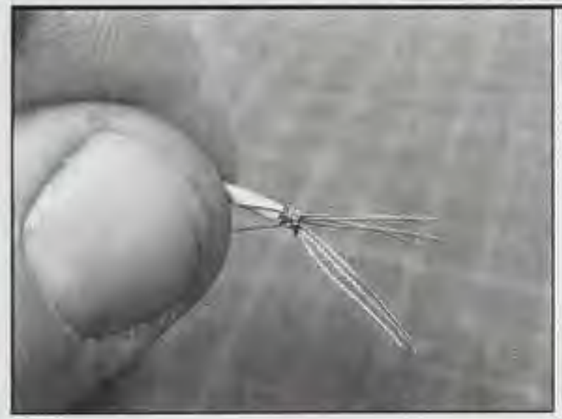
WHY? The nichrome wire will be used to light the pyrogen that will extend the piston at apogee. It's not possible to solder nichrome wire so looping it between strands of 22 gauge wire and then twisting them tight is an excellent way to ensure the igniter works consistently.



INSTRUCTIONS 37

Wrap the nichrome wire around the base of the 22 gauge wire 8 times.

WHY? Wrapping the nichrome wire several times around the base of the 22 gauge wire will ensure they maintain good contact with each other.



INSTRUCTIONS 38

Run the nichrome wire between the split strands one more time.



INSTRUCTIONS 39

Twist the strands together then, using a pair of needle nose pliers, twist the strands one or two more times to make sure they are good and tight.

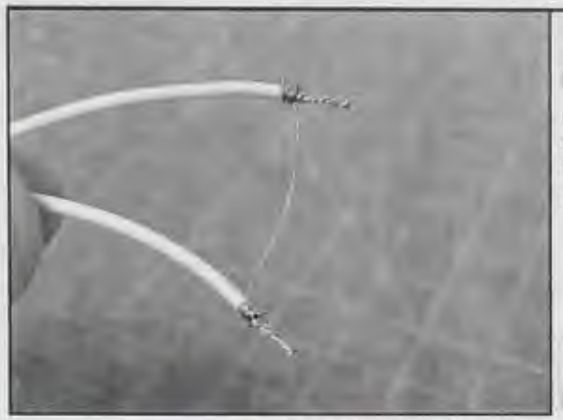
WHY? Twisting the strands locks the nichrome wire in place.



INSTRUCTIONS 40

Trim the 22 gauge strands to 3/8".

WHY? The nichrome wire is now locked in the strands of the 22 gauge wire.



INSTRUCTIONS 41

repeat steps 35 through 40 with the other piece of 22 guage wire. Make sure the gap of nichrome in between the two 22 gauge wires is no more than 1" long and no less than 3/4" long.

WHY? Nichrome wire will glow red hot when an electric current is passed through it. It's the heat from the nichrome wire that will ignite the pyrogen and activate the parachute piston.



INSTRUCTIONS 42

Solder the strands closed on both wires.

WHY? This step is OPTIONAL. Soldering the strands will keep the nichrome wire tightly locked in the 22 gauge wire. I've never had any of these igniters fail, with or without soldering.



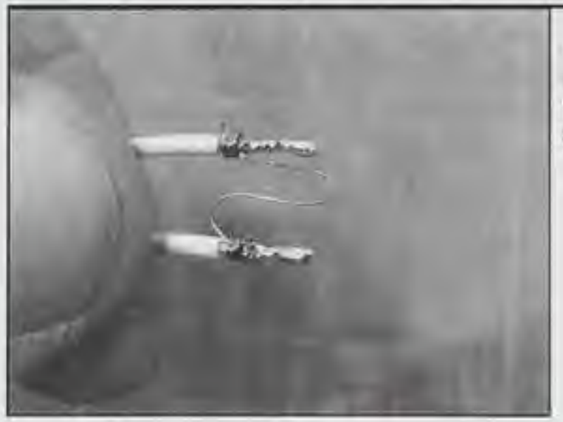
43 INSTRUCTIONS

Purchase the following part:
- 1/2" Square double-sided foam tape.

MATERIALS Polyethylene square double-sided foam tape 1/2" x 1/2".

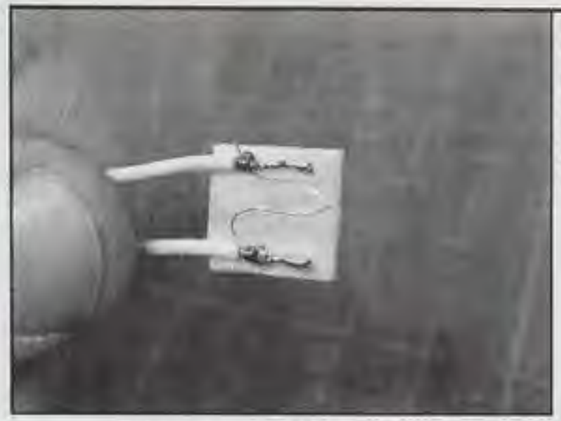
WHY? The double-sided foam tape has three purposes. It holds the nichrome and 22 gauge wires apart. It holds the igniter to the inside wall of the union and it ensures constant contact between the igniter and the pyrogen.

WEB www.mcmaster.com part number 75785T11.



44 INSTRUCTIONS

Form the nichrome wire into the shape of an *S* between the two 22 gauge wires.



45 INSTRUCTIONS

Remove the backing from one side of the foam tape. Push the 22 gauge wires and the nichrome wire into to the sticky side of the foam tape.

WHY? The double-sided foam tape has three purposes. It holds the nichrome and 22 gauge wires apart. It holds the igniter to the inside wall of the union and it ensures constant contact between the igniter and the pyrogen.



46 INSTRUCTIONS

On the other end of the igniter wires, bend the two ends up 90 degrees.

WHY? It's much easier to thread these two wires through the 5/32" hole in the 1/2" cap if they're bent at the end.



INSTRUCTIONS 47

Feed the two 22 gauge wires through the male union and out the 5/32" hole in the 1/2" cap.



INSTRUCTIONS 48

Pull the 22 gauge wires through the 5/32" hole until the igniter is inside the union. Remove the last piece of paper backing from the foam tape and stick the igniter to the inside wall of the union.
Make sure the top of the igniter is flush with the top of the union. See the picture for reference.

WHY?

The parachute piston only uses 1/2 teaspoon of pyrogen to eject the parachute. Since this is such a small amount and the pyrogen needs to be in contact with the igniter, we will be filling the union assembly with epoxy in a later step.



INSTRUCTIONS 49

Using a hot melt glue gun, seal the 5/32" hole on the 1/2" cap with hot melt glue.

MATERIALS

Hot melt glue gun and glue.

OPTIONS

Some silicone or masking tape can be used in place of hot melt glue.

WHY?

The hot melt glue will seal the 5/32" hole and prevent epoxy from seeping out while it hardens.



INSTRUCTIONS 50

Using two small clamps, clamp the 1/4-20 x 7/8" cap screws on both the 1" cap and the 1/2" union assembly so they are fixed in an upright position.

MATERIALS

Two small clamps.

OPTIONS

A drill press vise can be used in place of the clamps.



INSTRUCTIONS 51

Fill the bottom of the 1" cap with epoxy until it just covers the head of the cap screw. Let the epoxy harden.

MATERIALS

Loctite E-00CL fast setting epoxy.
Loctite applicator gun.
Loctite mixing nozzle.

OPTIONS

A less expensive epoxy can definitely be substituted for the epoxy in this step. The gun and mixing nozzle just make it easier.

WEB

www.mcmaster.com part number 6430A16.
www.mcmaster.com part number 74695A71.
www.mcmaster.com part number 74695A12.



INSTRUCTIONS 52

Fill the union assembly with epoxy to 1/2" of the top. Let the epoxy harden. DO NOT get any epoxy on the igniter.

WHY?

In both this step and the previous step, epoxy is used to seal the holes where the cap screws penetrate the piston. The epoxy will make an air tight seal inside the piston.

WHY?

The parachute piston only uses 1/2 teaspoon of pyrogen to eject the parachute. Since this is such a small amount and the pyrogen needs to be in contact with the igniter.



INSTRUCTIONS 53

Put a liberal amount of plumbers grease around the base of the o-ring on the 1/2" pipe.

MATERIALS

Plumbers grease.

WHY?

The grease will make an air tight seal between the o-ring and the PVC. When the piston is activated, the hot gasses will stay inside the piston due to the seal provided by the grease and the o-ring.

WEB

www.homedepot.com part number 678831 or similar.



INSTRUCTIONS 54

Carefully slide the 1/2" pipe inside the 1" pipe. The bottom of the 1/2" pipe will go through the 7/8" hole in the 1" cap. Push the greased o-ring in the tapered end of the 1" pipe until the coupling is flush with the end of the pipe. See the picture in step #55 and #56 for clarification.



INSTRUCTIONS 55

The 1/2" pipe should fit through the 1" cap like this.

INSTRUCTIONS 56

The coupling should fit flush in the 1" pipe. Wipe off any excess grease.



INSTRUCTIONS 57

Once the epoxy in the 1" cap has hardened, glue the cap on the open end of the 1" pipe.

MATERIALS

I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 58

The completed piston should look like this.

WHY?

The piston is a single use device. Do not extend the piston. Leave it in this position until it's activated.



INSTRUCTIONS 59

Purchase a bag of potassium nitrate and measure out about a pound.

MATERIALS

Granular or prilled potassium nitrate, Kno3.
Keep away from laboratory grade potassium nitrate as the high purity is not necessary and the price is too high. Agricultural grade potassium nitrate will work just fine.

OPTIONS

Granular potassium nitrate can be used as is. Prilled potassium nitrate is in the form of little balls. As long as these balls are not coated in clay, the prills can be ground down in a coffee grinder and used as granular potassium nitrate.

WEB

Many sources online supply potassium nitrate in various forms and weights. A quick Google search will turn up several suppliers.



INSTRUCTIONS 60

Put the potassium nitrate in a steel pan in a toaster oven or conventional oven preheated to 300 degrees for 30 minutes.
Remove the potassium nitrate and let it cool slightly.

WHY?

Never mix anything with the potassium nitrate before it is heated. Only heat the potassium nitrate by itself.

WHY?

Potassium nitrate is hygroscopic, meaning it will absorb moisture from the air. Heating it at 300 degrees for 30 minutes will drive out all the moisture.

WEB

More information about potassium nitrate can be found at www.wikipedia.org under Kno3.



INSTRUCTIONS 61

Put the potassium nitrate through a coffee grinder set to its finest setting.

WHY?

Purchase a coffee grinder with the largest capacity as possible. This will make it much easier to grind the potassium nitrate especially if you have prilled potassium nitrate and need to grind all of it.

WHY?

I've never understood why coffee grinders have half a dozen safety interlocks. You can't even fit your fingers inside near the blade. Yet a blender, that you actually can stuff your whole fist into, has none.
Do yourself a favor and spend an afternoon removing or disabling all the safety interlocks on the coffee grinder. Since you're an adult, like me, and not a two year old, this will make your life a lot easier.



INSTRUCTIONS 62

Using a clean container, measure out 0.65 pounds potassium nitrate

WHY?

Make sure you zero out the scale after the container has been placed on the scale so the only material weighed is the potassium nitrate.

WHY?

Digital scales vary in quality and cost. An inexpensive scale can be found online with a little searching. The scale must have a resolution of 1/100th of a pound.



INSTRUCTIONS 63

Measure out 0.35 pounds powdered sugar.

MATERIALS

Powdered sugar.

WHY? Powdered sugar will work better than granular sugar because of the smaller particle size.

WHY? Make sure you zero out the scale after the container has been placed on the scale so the only material weighed is the powdered sugar.



INSTRUCTIONS 64

Throughly mix the potassium nitrate together with the powdered sugar.
The mixture is now flammable.
Put the pyrogen mixture into an air tight container.

MATERIALS

Any air tight container similar to www.mcmaster part number 4176T6.



INSTRUCTIONS 65

Purchase a plastic funnel and a 1/2 teaspoon measuring spoon.

MATERIALS

Plastic funnel.
1/2 teaspoon measuring spoon.

WHY? The parachute piston only needs 1/2 teaspoon of pyrogen to operate properly. DO NOT add more than 1/2 teaspoon or the piston will explode.



INSTRUCTIONS 66

Screw the female section of the union on to the male section.
Using a small clamp, clamp the 1/4-20 x 7/8" cap screw on the 1/2" union assembly so that it is fixed in an upright postilion.

MATERIALS

One small clamp.

OPTIONS

A drill press vise can be used in place of the clamp.

WHY? Having the female section of the union attached to the male section will make it easier to add the pyrogen into the union.



INSTRUCTIONS 67

Measure a LEVEL 1/2 teaspoon of pyrogen mix.

MATERIALS

1/2 teaspoon measuring spoon.

WHY?

The parachute piston only needs 1/2 teaspoon of pyrogen to operate properly. DO NOT add more than 1/2 teaspoon or the piston will explode.



INSTRUCTIONS 68

Position a plastic funnel over the top of the union. Pour the 1/2 teaspoon of pyrogen into the funnel and down into the union.

MATERIALS

Plastic funnel.



INSTRUCTIONS 69

Remove the female section of the union and make sure the pyrogen is level with the top of the male section. DO NOT add more if it is a little low. As long as the pyrogen is touching the igniter the piston will work.

WHY?

Done correctly, the pyrogen will fill the cavity in the union so that it is level with the top of the male section. This will ensure that the pyrogen is always in contact with the igniter no matter what position the rocket is



INSTRUCTIONS 70

Remove the slip insert from the female section of the union and use it to trace a circle on a piece of heavy duty aluminum foil.
Cut out the foil circle.

MATERIALS

Black *Sharpie* or similar permanent marker.
Heavy duty aluminum foil or regular aluminum foil.
Scissors.

OPTIONS

DO NOT use other materials for this step. Heavier materials will make the piston explode.

WHY?

The aluminum foil will keep the pyrogen in place but will tear easily when the pyrogen is ignited.



INSTRUCTIONS 71

Place the aluminum foil disc over the o-ring on the male section of the union.



OPTIONS DO NOT use other materials for this step. Heavier materials will make the piston explode.

WHY? The aluminum foil will keep the pyrogen in place but will tear easily when the pyrogen is ignited.



INSTRUCTIONS 72

place the slip insert from the female section of the union on top of the aluminum foil disc.





INSTRUCTIONS 73

Screw on the union collar. Hand tighten the collar.





INSTRUCTIONS 74

The finished piston union should look like this.





INSTRUCTIONS 75

Glue the union to the piston using PVC glue.
Trim the two igniter wires to 4".



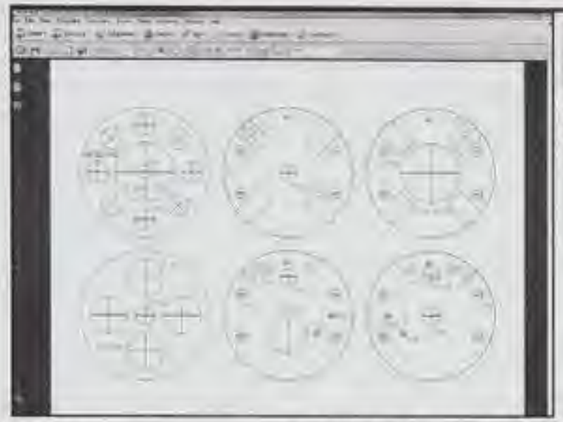
MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.

INSTRUCTIONS 76



The finished parachute piston should now look like this. Continue on through the next few steps to make the piston disc.





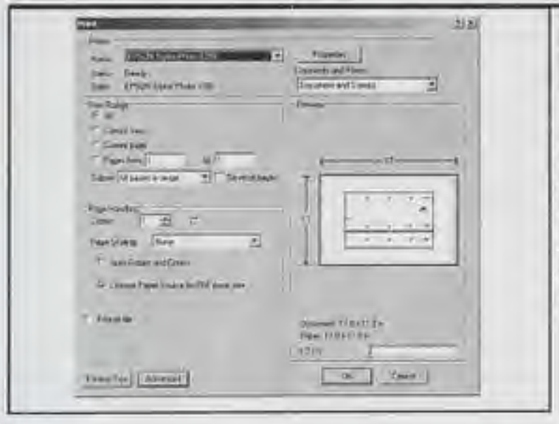
INSTRUCTIONS 77

Download and print out the following template:
• *Bulkhead Template 8.5 x 11.*

MATERIALS Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 78

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



INSTRUCTIONS 79

Cut out the template marked *Piston* as accurately as possible.

MATERIALS

Razor blade or scissors.

INSTRUCTIONS 80



Purchase the following parts:
• Delrin plastic disc 3" diameter 1" long.
If you built the apogee detector in chapters 4&5, you will have this piece already.

MATERIALS

3" Diameter delrin rod 1" long.

WHY?

Delrin is an inexpensive black thermoplastic that is easy to cut and machine. It is sturdy enough to act as the piston disc to push out the parachute at apogee.

WEB

www.mcmaster.com part number 9986K12.



INSTRUCTIONS 81

Read step #82 before starting this step.
Using a belt sander, evenly sand down the sides of the delrin disc.

OPTIONS

A hand sander or sandpaper can be used in place of a belt sander.

WHY?

The piston disc needs to travel up the inside of the rocket body without resistance. For this reason the disc is going to be sanded down about 1/16" smaller than the inside of the rocket body.



INSTRUCTIONS 82

When the piston is finished, it should easily fit in the upper rocket body. It should slide in and out of the rocket body with a little room to spare.

WHY?

The piston disc needs to travel up the inside of the rocket body without resistance. For this reason the disc is going to be sanded down about 1/16" smaller than the inside of the rocket body.



INSTRUCTIONS 83

Lightly sand down both faces on the disc until they are flat and perpendicular with the sides of the disc.



OPTIONS

A hand sander or sandpaper can be used in place of a belt sander.



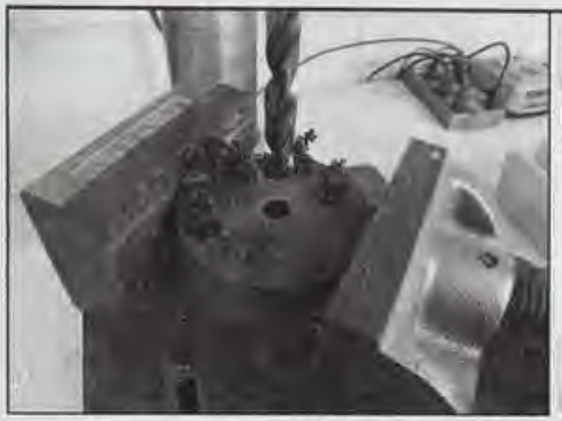
INSTRUCTIONS 84

Place the *Piston* template on either side of the disc and mark the four 7/8" holes around the edge and the 7/16" hole in the center with a center punch.



OPTIONS

A sharp nail can be used in place of a center punch.



INSTRUCTIONS 85

Drill the 7/16" hole in the center of the disc all the way through the disc.



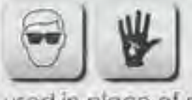
OPTIONS

A cordless drill can be used in place of a drill press. Just make sure the holes are drilled perpendicular to the face of the disc.



INSTRUCTIONS 86

Using a spade bit, drill the four 7/8" holes around the edge of the disc all the way through the disc.



OPTIONS

A cordless drill can be used in place of a drill press. Just make sure the holes are drilled perpendicular to the face of the disc.

WHY?

The 7/8" holes in the piston disc serve two purposes. First the holes provide a place for the parachute shock cord to travel through. Second, the holes prevent the piston disc from forming a vacuum behind it when it's pushed up through the rocket body.

WHY?

A spade bit is used for fast drilling of holes in wood and plastic. Spade bits have a forged, flat paddle with a guide point and cutting edges on either side.



INSTRUCTIONS 87

Purchase the following part:
• Two steel press fit threaded inserts 1/4-20 x 15/32".

MATERIALS Two (one pack) steel press fit threaded inserts 1/4-20 x 15/32".

WHY? Threaded inserts will allow you to bolt and un-bolt the piston disc numerous times. If the threads were made directly in the plastic rod, the threads wouldn't be as strong and would degrade with each use.

WEB www.mcmaster.com part number 97191A230.



INSTRUCTIONS 88

Using a drill press vise, push a threaded insert into the 7/16" hole on the disc. Repeat on the opposite side of the disc.

OPTIONS A hammer can be used in place of a drill press vise.



INSTRUCTIONS 89

The finished piston disc should look like this.



INSTRUCTIONS 90

Screw the piston disc on the top of the 1" cap. Hand tighten the disc only.



CHAPTER 7

PARACHUTE AND PARACHUTE RIGGING

The parachute shock cord is stored around the parachute piston. This saves space and weight in the upper section of the rocket allowing the rocket to go higher and faster. Rigging the parachute is a simple task and can be completed in a matter of minutes.



INSTRUCTIONS

01

Purchase the following parts:
- Double braided polyester rope.
- Two steel threaded connectors.
- Twelve steel hose clamps.

MATERIALS

50 Feet double braided polyester rope 1/4" diameter 400 pound test.
Two steel threaded connectors 3/16" diameter 600 pound test.
Twelve double pinch steel hose clamps 5/16" to 7/16".

WEB

www.mcmaster.com part number 3789T312.
www.mcmaster.com part number 8947T15.
www.mcmaster.com part number 6541K51.



INSTRUCTIONS

01

Purchase the following parts:
- Straight jaw pincer.
- Heat shrink tubing 3/4" to 3/8".
- One 60" surplus parachute.

MATERIALS

Straight jaw installation pincer.
Heat shrink tubing 3/4" to 3/8" - black.
60" White surplus parachute.

OPTIONS

The straight jaw pincers work so well tightening the hose clamps on the shock cord that I felt I needed to include them as a part. I'm sure there are tools that could be used as an alternative but I wouldn't want to risk the rocket for a $22.00 tool.

WEB

www.mcmaster.com part number 6541K67.
www.mcmaster.com part number 7496K19.
www.aerocon.com part number P60WHITE.



INSTRUCTIONS 03

Remove and discard the two canvas bags the parachute comes with.

WHY? Since the rocket uses a piston to push out the parachute and the hot gasses are contained inside the piston, there's no need to protect the parachute from heat.



INSTRUCTIONS 04

Using a pair of linemans pliers, cut and discard the braided metal rope at the end of the parachute shroud lines.



INSTRUCTIONS 05

Measure out 23 feet of 1/4" polyester rope. Put a small piece of masking tape around the rope at the 23 foot mark.

MATERIALS Masking tape

WHY? Braided polyester rope has a tendency to unravel when cut. The masking tape will prevent that.



INSTRUCTIONS 06

Cut the 1/4" rope in the middle of the masking tape.

MATERIALS Razor blade or scissors.

WHY? Braided polyester rope has a tendency to unravel when cut. The masking tape will prevent that.



07 INSTRUCTIONS

Using a propane torch, melt the cut end of the rope. Putting the cut end of the rope close to the flame is enough to melt the polyester. It's not necessary to melt more than the exposed end of the rope. Repeat this step with the other end of the 23 foot section so both ends are sealed. Put the 23 foot section of rope aside.

MATERIALS

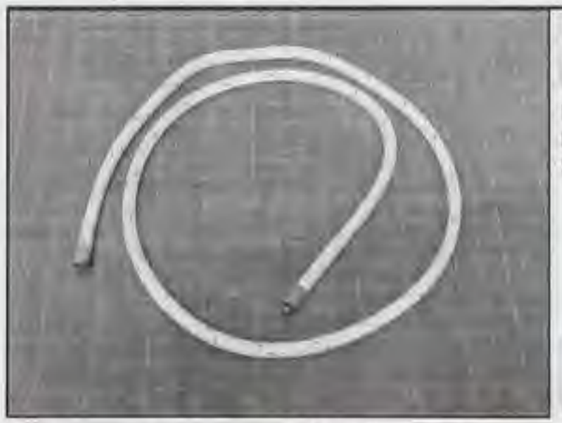
Propane torch.

OPTIONS

A match or lighter can be used in place of a propane torch.

WHY?

Melting the polyester braids will bond them all together and prevent them from unraveling.



08 INSTRUCTIONS

Repeat steps #5 & 6 and cut a piece of rope 36" long.
Repeat step #7 and seal both ends of the rope.

MATERIALS

Propane torch.

OPTIONS

A match or lighter can be used in place of a propane torch.

WHY?

Melting the polyester braids will bond them all together and prevent them from unraveling.



09 INSTRUCTIONS

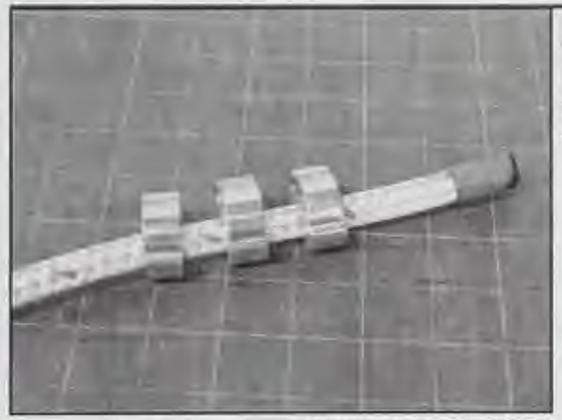
Cut two 2" sections of 3/4" heat shrink tubing.

MATERIALS

Razor blade or scissors.

WHY?

The heat shrink tubing will be used to cover the edges of the hose clamps. This will prevent any damage from the edges but more importantly it will prevent the clamps from getting snagged or tangled.



10 INSTRUCTIONS

Thread one end of the 36" length of rope through three hose clamps.

WHY?

Three clamps will hold the rope tight even under the most extreme stresses.



INSTRUCTIONS 11

Loop the end of the rope back through the three clamps so that there is about 1 1/2" space between the clamps and the top of the loop. Make sure the clamps are about 1/2" apart and the rope end is just past the last clamp.

WHY? Three clamps will hold the rope tight even under the most extreme stresses.



INSTRUCTIONS 12

Using straight jaw pincers, pinch one side of each clamp, one clamp at a time. Turn the rope over and pinch the other side, one clamp at a time. Go over the clamps one more time with the pincers to make sure they're tight.

WHY? Normally, these clamps are used to form a tight seal between hydraulic fittings and hydraulic hose, they work equally well binding the loops of the parachute rigging.



INSTRUCTIONS 13

The loop at one end of the 36" rope section should now look like this.



INSTRUCTIONS 14

Using a heat gun, shrink a 2" piece of heat shrink tubing over all three clamps.

OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The heat shrink tubing will be used to cover the edges of the hose clamps. This will prevent any damage from the edges but more importantly it will prevent the clamps from getting snagged or tangled.



INSTRUCTIONS 15

Get the nosecone that was built in chapter 3 and set it on the work surface. Here you can see I've painted mine orange.

INSTRUCTIONS 16

Put one 2" piece of heat shrink tubing and three clamps on the open end of the 36" rope.



WHY? This end of the 36" rope will attach to the nosecone.



INSTRUCTIONS 17

Loop the open end of the 1/4" rope through the eye bolt on the bottom of the nosecone, then through the three clamps so that there is about 1 1/2" space between the clamps and the top of the loop.
Make sure the clamps are about 1/2" apart and the rope end is just past the last clamp.

WHY? Three clamps will hold the rope tight even under the most extreme stresses.

INSTRUCTIONS 18

Using the straight jaw pincers, pinch one side of each clamp, one clamp at a time. Turn the rope over and pinch the other side, one clamp at a time.
Go over the clamps one more time with the pincers to make sure they are tight.



WHY? Normally, these clamps are used to form a tight seal between hydraulic fittings and hydraulic hose, they work equally as well binding the loops of the parachute rigging.



INSTRUCTIONS 19

Using a heat gun, shrink a 2" piece of heat shrink tubing over all three clamps.

OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The heat shrink tubing will be used to cover the edges of the hose clamps. This will prevent any damage from the edges but more importantly it will prevent the clamps from getting snagged or tangled.



INSTRUCTIONS 20

The rigging for the nosecone should now look like this. Put the nosecone aside for now.



INSTRUCTIONS 21

Get the 23' section of rope from step #7 and put it on the work surface.



INSTRUCTIONS 22

Cut two 2" sections of 3/4" heat shrink tubing.

MATERIALS Razor blade or scissors.

WHY? The heat shrink tubing will be used to cover the edges of the hose clamps. This will prevent any damage from the edges but more importantly it will prevent the clamps from getting snagged or tangled.



INSTRUCTIONS 23

Repeat steps #10-13 on both ends of the 23' rope.

INSTRUCTIONS 24

Using a heat gun, shrink a 2" piece of heat shrink tubing over all three clamps on both ends.



OPTIONS A lighter or torch set on low can be used to shrink the heat shrink tubing in place of a heat gun but the risk of over heating the tubing is substantial.

WHY? The heat shrink tubing will be used to cover the edges of the hose clamps. This will prevent any damage from the edges but more importantly it will prevent the clamps from getting snagged or tangled.



INSTRUCTIONS 25

Put two steel threaded connectors on either end of the 23' rope.

WHY? The threaded connectors will make it easy to launch and re-launch the rocket.



INSTRUCTIONS 26

Purchase the following parts:
- Latex rubber bands.
- O-rings 3/8" ID x 1/2" OD.

MATERIALS Natural latex rubber bands #14.
Buna-N o-rings 3/8" ID x 1/2" OD.

WHY? The rubber bands hold the shock cord in place around the parachute piston and prevent it from getting tangled during deployment.

WEB www.mcmaster.com part number 1220T52.
www.mcmaster.com part number 2418T118.



INSTRUCTIONS 27

Put the completed parachute piston from chapter 6 on the work surface.



WHY? The shock cord will be stored around the parachute piston.



INSTRUCTIONS 28

Unscrew the piston disc and put it aside.





INSTRUCTIONS 29

Lay the parachute piston out on the work surface in front of you. Take one end of the 23' rope and lay it next to the piston so that the threaded coupling is lined up with the 1/2" PVC cap.



WHY? Eventually this end of the shock cord will be attached to the apogee detector.



INSTRUCTIONS 30

Loop the rope at the end of the piston and run it back towards the threaded coupling.





INSTRUCTIONS 31

Take a 3/8" o-ring and slip it over the loop of rope.

WHY? The o-rings will hold the loops of rope in place so they can be wrapped around the piston. They will be removed later.



INSTRUCTIONS 32

Loop the rope at the bottom of the piston and run it back towards the top.



INSTRUCTIONS 33

Take a 3/8" o-ring and slip it over the loop of rope at the bottom.

WHY? The o-rings will hold the loops of rope in place so they can be wrapped around the piston. They will be removed later.



INSTRUCTIONS 34

Repeat steps #30-33 until all but 12" of the 23' rope has been folded and secured with o-rings.

WHY? It's not critical that the loops of rope be exactly the same size. Some variation in size is fine.



INSTRUCTIONS 35

Make sure there is at least 12" of extra rope at the end of the folded sections.



WHY? This extra section of rope will be used to attach the parachute and nosecone in the next chapter.



INSTRUCTIONS 36

Start to roll the piston towards you, rolling the sections of rope around it as you go.



WHY? Storing the shock cord around the piston is a good use of space.

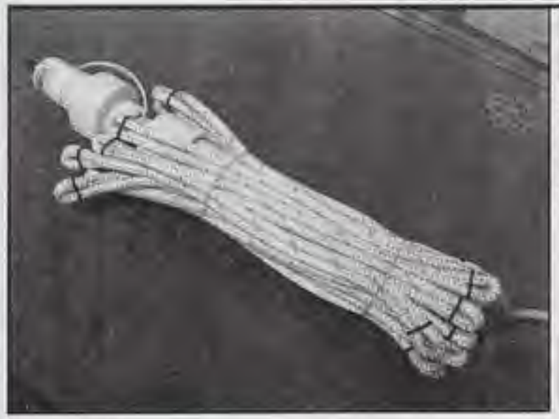


INSTRUCTIONS 37

Once all the rope sections have been rolled around the piston, hold them tightly in your hand and proceed to the next step.



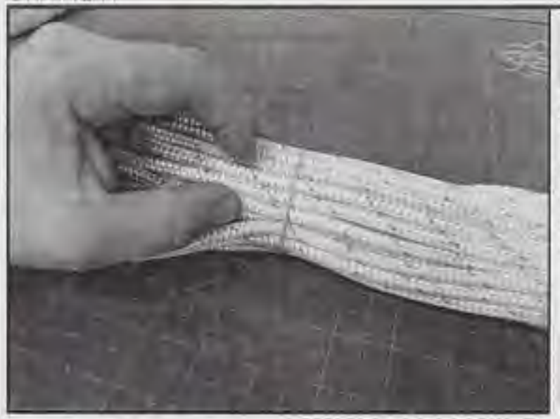
WHY? Don't worry if the rope sections overlap or aren't straight, that will be fixed soon.



INSTRUCTIONS 38

Put two rubber bands over the rope sections to hold them in place around the piston.
The rubber bands should be doubled up to hold the rope sections tightly.

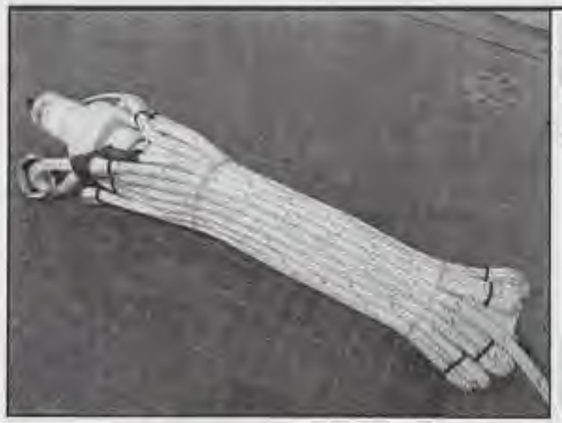




INSTRUCTIONS 39

Starting with the end of the rope with the threaded coupling near the 1/2" PVC cap, organize the rope sections so they are in order. Make sure the sections follow a sequence from one to the next and do not overlap or go under other ropes.

WHY? This step is important so the shock cord deploys correctly and doesn't get tangled.



INSTRUCTIONS 40

The rope sections around the piston should now look like this, in order and neat.

WHY? This step is important so the shock cord deploys correctly and doesn't get tangled.



INSTRUCTIONS 41

Add two more doubled up rubber bands to the rope sections around the piston. You should have a total of four.

WHY? The rubber bands will hold the looped sections of rope in place.



INSTRUCTIONS 42

remove the o-rings from the loops of rope near the top of the piston. Put them away to be used at another time.

WHY? If the o-rings where left on the rope loops, the rope would get tangled and would not play out when the parachute is deployed.



INSTRUCTIONS 43

remove the o-rings from the loops of rope near the bottom of the piston. Put them away to be used another time.

WHY? If the o-rings where left on the rope loops, the rope would get tangled and would not play out when the parachute is deployed.



INSTRUCTIONS 44

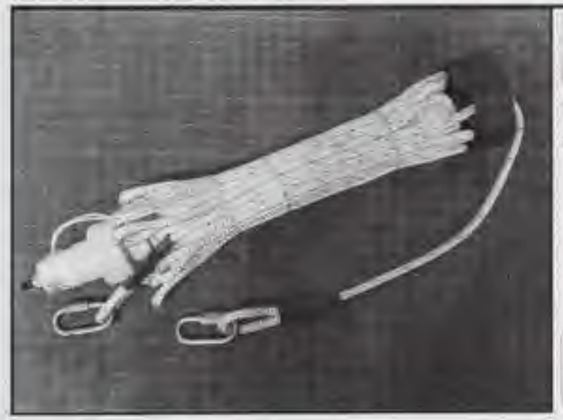
Screw the piston disc back on the top of the piston. Hand tighten the piston disc only.



INSTRUCTIONS 45

Remove the threaded coupling from the 12" section of rope at the top of the piston. Thread the rope loop through the hole on the piston disc right above it and reinstall the threaded coupling.

WHY? The shock cord will be pulled through this hole when the piston pushes the parachute out at apogee.



INSTRUCTIONS 46

The finished parachute piston with shock cord should now look like this.



INSTRUCTIONS 47

Place the parachute on the work surface.

OPTIONS

The parachute used for this project is a 60" diameter military surplus parachute with fiberglass shroud lines. It is very strong and I've never had one fail. However, there are many parachutes available for rocket recovery, any one of which would make an adequate replacement.



INSTRUCTIONS 48

Inspect the parachute and shroud lines for rips, tears or any damage that might impede the parachute's ability to recover the rocket properly.

WHY?

Military surplus are goods that are sold or otherwise disposed of when no longer needed by the military.



INSTRUCTIONS 49

Lay the parachute out on the work surface. Gather up all the shroud lines in one hand so they are even and grouped together at the base of the parachute.

OPTIONS

There are many ways to fold a parachute. this is just one that works well for me.



INSTRUCTIONS 50

Fold the parachute in on itself along the middle.



INSTRUCTIONS 51

Fold one third of the length of the parachute over on itself.



INSTRUCTIONS 52

Fold the final third of the length of the parachute over on itself.



INSTRUCTIONS 53

Fold the parachute in half.



INSTRUCTIONS 54

Roll the two halves together.



INSTRUCTIONS 55

Start to roll the shroud lines tightly around the parachute bundle. Roll the lines one next to another so they don't overlap.



INSTRUCTIONS 56

When you reach the end of the bundle, continue to wrap the lines up toward the other end.



INSTRUCTIONS 57

Wrap the shroud lines tightly around the bundle until all the lines are wrapped up.



INSTRUCTIONS 58

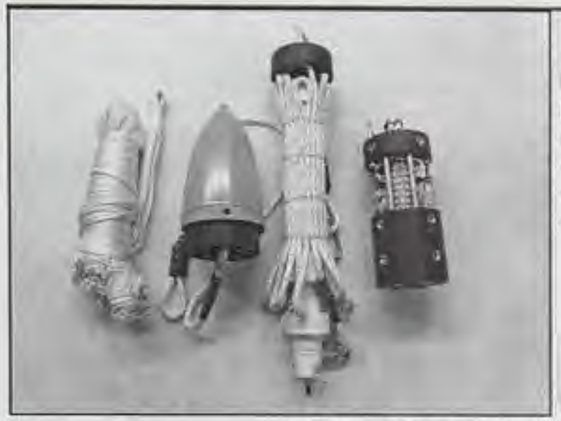
The finished parachute bundle should look like this with all the shroud lines around the parachute and the loop at the end of the lines folded neatly next to it.



CHAPTER 8

ASSEMBLING THE UPPER BODY SECTION

By this time, all the parts that make up the upper body section of the rocket have been constructed and it's just a matter of putting them together. If you've followed the instructions and used the templates, everything should fit together perfectly.



INSTRUCTIONS 01

Put the following parts on your work surface:
- Nosecone and nosecone shock cord line.
- Parachute and parachute shroud lines.
- Parachute piston and shock cord lines.
- Apogee detector.

WHY? The upper body section of the rocket holds the nosecone, parachute and parachute rigging, parachute piston and apogee detector.



INSTRUCTIONS 02

Purchase the following parts:
- 3/4" x 5/16" Foam weather stripping.
- New 9 volt battery.

Put the following part on your work surface:
- 3" ABS upper body section.

MATERIALS 3/4" x 5/16" Foam weather stripping.
One new 9 volt battery.

WEB www.homedepot.com part number 518425.
www.mcmaster.com part number 71455K56.



INSTRUCTIONS 03

Purchase the following parts:
- Eight 1/4-20 x 5/8" button head hex screws.
- Two 15" nylon cable ties.

MATERIALS Eight 1/4-20 x 5/8" button head hex screws.
Two 15" nylon cable ties.

OPTIONS Any type of 1/4-20 x 5/8" screws can be used but I like the button head hex screws because the screw heads are more aerodynamic. I realize it really doesn't make any difference in the performance of the rocket. I just think they make the rocket look sleeker.

WEB www.mcmaster.com part number 91255A539.
www.mcmaster.com part number 7130K572.



INSTRUCTIONS 04

Cut a 1" length of foam tape.

OPTIONS Later in the chapter the 9 volt battery will be anchored in the apogee detector by a 1/4-20 x 1 1/2" screw. This screw will hold the battery tightly in place while the rocket is being transported and also in flight. The foam tape will be put on the 9 volt battery to prevent any horizontal movement. I don't think the foam tape is really necessary because the screw should hold the battery firmly in place. I've always used the foam tape and have never had a problem with the battery coming out of the battery holder, so it's really up to you if you want to skip this step.



INSTRUCTIONS 05

Place the 9 volt battery on the work surface so the negative terminal is on your right and the positive terminal is on your left. Place the foam tape on top of the battery.

WHY? The foam tape will prevent the battery from moving horizontally when the rocket is in flight.



INSTRUCTIONS 06

Install the 9 volt battery into the battery holder on the apogee detector. The foam tape should be on the outside.
Press the battery firmly into the contacts on the battery holder.

WHY? Since the apogee detector's circuit is open and there's no phantom load, the battery can be stored in the apogee detector for extended periods of time without any voltage loss. This is one of the advantages of the apogee detector.

WHY? From this point on the apogee detector is ARMED and will send voltage to the terminal block on top of the apogee detector if the safety pin is removed and the apogee detector is tipped. Make sure the safety pin is SECURE before proceeding.

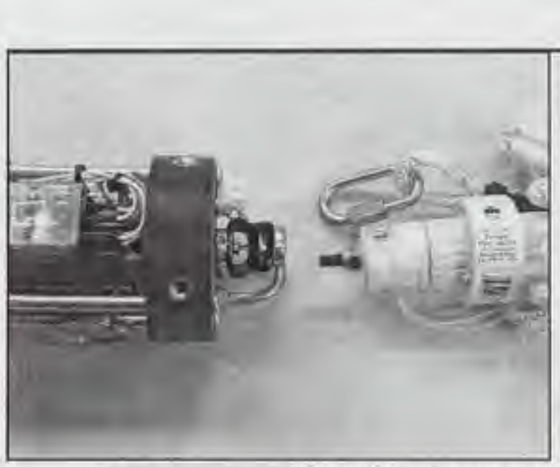
WHY? phantom load refers to the electric power consumed by electronic appliances while they are switched off or in a standby mode.



INSTRUCTIONS 07

Tighten the 1/4-20 x 1 1/2" machine screw directly on top of the battery until it comes in contact with the battery.
It's not important to torque down on the screw, it only needs to be in contact with the battery to prevent it from moving.

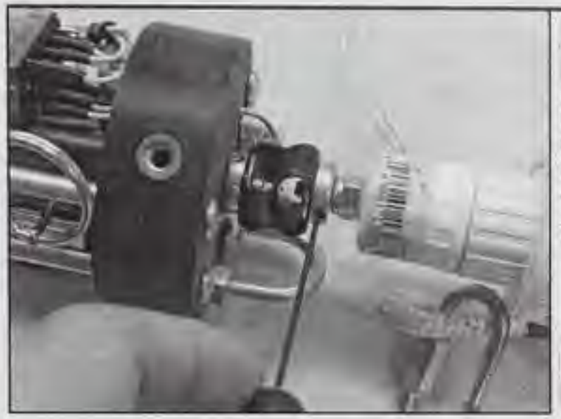
OPTIONS If you'd like, all this can be done at the launch site but having everything ready to go and easy to transport is a great advantage of the rocket design.



INSTRUCTIONS 08

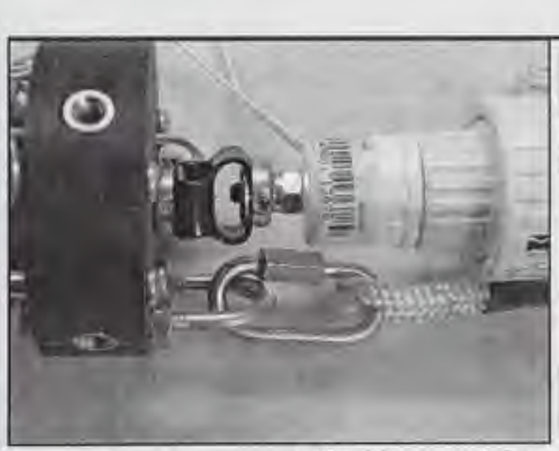
Line up the apogee detector and the parachute piston.

WHY? The piston is connected to the flexible coupling on the top of the apogee detector. This way, if there is any misalignment issues between the piston and the apogee detector, the coupling will compensate.



INSTRUCTIONS 09

Put the 1/4-20 screw on the bottom of the piston into the flexible coupling on the top of the apogee detector. Make sure the piston ignition wires are on the same side as the terminal block on the top of the apogee detector.
Tighten the set screw on the flexible coupling.



INSTRUCTIONS 10

Attach the parachute shock cord to the apogee detector u-bolt with a steel threaded connector.

WHY? The parachute is securely connected to the apogee detector which is securely connected to the rocket body.



INSTRUCTIONS 11

Strip 1/4" insulation off both piston ignition wires.

INSTRUCTIONS 12

Attach both piston ignition wires to the two pole terminal block on top of the apogee detector. It doesn't matter which wire goes to which terminal.



WHY?

The apogee detector is ARMED and will send voltage to the terminal block on top of the apogee detector if the safety pin is removed and the apogee detector is tipped. Make sure the safety pin is SECURE before proceeding.



INSTRUCTIONS 13

Run the two piston ignition wires back across the terminal block and secure the wires to the flexible coupling with a small zip tie.

MATERIALS

Small zip tie.

WHY?

Putting a small zip tie on the wires will keep them out of the way when the apogee detector is installed in the rocket body.

WEB

www.mcmaster.com part number 7130K52.

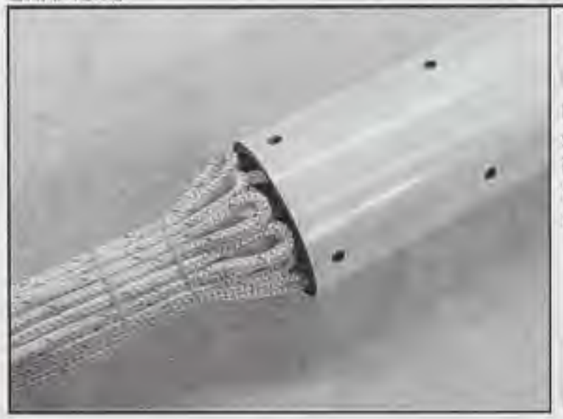
INSTRUCTIONS 14

Place the upper rocket body near the top of the piston. Make sure the end with the holes is next to the top of the piston.
Feed the threaded coupling and the 12" extra shock cord on top of the piston disc into the rocket body.



WHY?

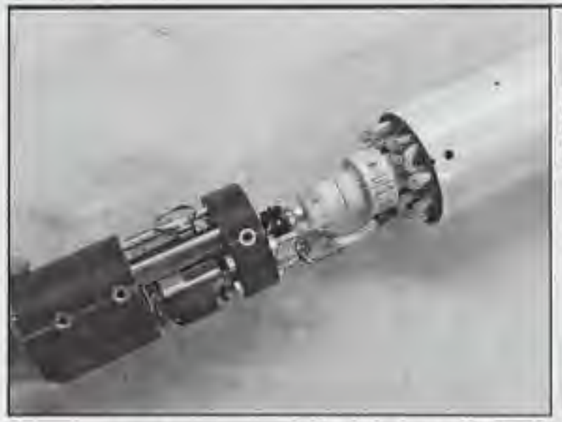
The entire piston and apogee detector will now be pushed up into the rocket body and screwed in place.



INSTRUCTIONS 15

Insert the piston disc into the upper rocket body section. Make sure the shock cord loops fit neatly inside the rocket body and are not kinked. Continue to insert the piston with the shock cord into the rocket body.





INSTRUCTIONS 16

Once the piston is almost inside the rocket body, line up the center line on the apogee detector with the center line notch on the rocket body.



WHY? Having a center line is the easiest way to make sure everything lines up and fits correctly.

WHY? The piston disc and the shock cord should fit easily up into the rocket body.



INSTRUCTIONS 17

Start to insert the top of the apogee detector into the rocket body. Make sure the center line notch on the rocket body lines up with the center line on the apogee detector.



WHY? Having a center line is the easiest way to make sure everything lines up and fits correctly.

INSTRUCTIONS 18

Stand the rocket section upright.



WHY? In the next few steps, the safety pin will be removed. This will not be a problem as long as the rocket is upright. The apogee detector is ARMED and if the rocket is put on it's side the piston will fire.

WHY? Make sure your work surface is LEVEL. The rocket section can easily fall over at this point.



INSTRUCTIONS 19

Remove the safety pin.

WHY? In the next few steps, the safety pin will be removed. This will not be a problem as long as the rocket is upright. The apogee detector is ARMED and if the rocket is put on it's side the piston will fire.

WHY? Make sure your work surface is LEVEL. The rocket section can easily fall over at this point.



INSTRUCTIONS 20

Be careful when inserting the apogee detector into the upper rocket body. Take your time. Press the foam tape down so it will fit inside the rocket body.

WHY? In the next few steps, the safety pin will be removed. This will not be a problem as long as the rocket is upright. The apogee detector is ARMED and if the rocket is put on it's side the piston will fire.

WHY? Make sure your work surface is LEVEL. The rocket section can easily fall over at this point.

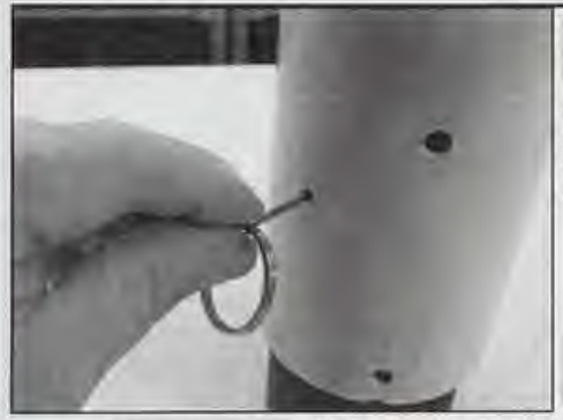


INSTRUCTIONS 21

Insert the apogee detector into the upper rocket body section so that the holes in the rocket body line up with the threaded inserts in the apogee detector.

WHY? In the next few steps, the safety pin will be removed. This will not be a problem as long as the rocket is upright. The apogee detector is ARMED and if the rocket is put on it's side the piston will fire.

WHY? Make sure your work surface is LEVEL. The rocket section can easily fall over at this point.



INSTRUCTIONS 22

Put the safety pin through the 5/32" hole on the side of the rocket body. The safety pin should go all the way in the fiberglass tube on the apogee detector.

WHY? Make sure your work surface is LEVEL. The rocket section can easily fall over at this point.



INSTRUCTIONS 23

Make sure the safety pin is inserted all the way in.





INSTRUCTIONS 24

Put eight 1/4-20 x 5/8" button head hex screws into the threaded inserts on the apogee detector. Hand tighten all the screws until you are sure they all line up properly.



OPTIONS

Any type of 1/4-20 x 5/8" screws can be used but I like the button head hex screws because the screw heads are more aerodynamic. I realize it really doesn't make any difference in the performance of the rocket. I just think they make the rocket look sleeker.



INSTRUCTIONS 25

Tighten the 1/2-20 x 5/8" screws with a 5/32" hex key. Tighten the screws until they're snug, there is no need to over-tighten them.





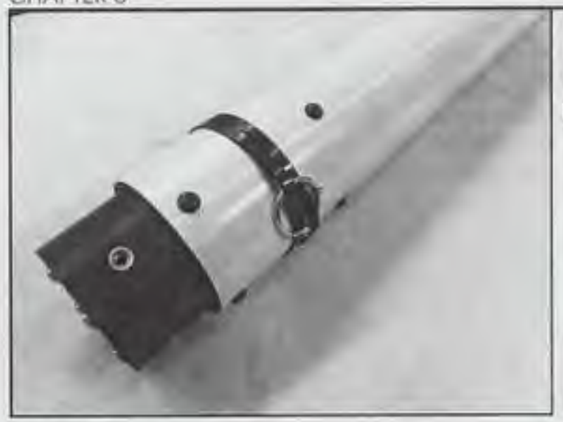
INSTRUCTIONS 26

Attach two 15" zip ties to the safety pin so that it can't be accidentally removed during transport.



OPTIONS

Masking tape can be used in place of the zip ties as long as the safety pin is secure.



INSTRUCTIONS 27

lay the upper rocket section on its side.





INSTRUCTIONS 28

The 12" section of rope at the top of the piston should lay out the top of the rocket body.



WHY? This threaded connector will be attached to the parachute and the nosecone.



INSTRUCTIONS 29

Put the folded parachute inside the upper rocket body so that the loop for the shroud lines and the threaded connector are together.





INSTRUCTIONS 30

Attach the shock cord from the nosecone and the parachute shroud lines to the threaded connector. Tighten the threaded connector.





INSTRUCTIONS 31

Push the parachute all the way into the rocket body until it sits up against the piston disc.

OPTIONS

Depending on how you folded the parachute, you may need to unwrap the shroud lines, fold it in half again and then re-wrap it so the parachute fits in the rocket body with enough room for the nosecone.

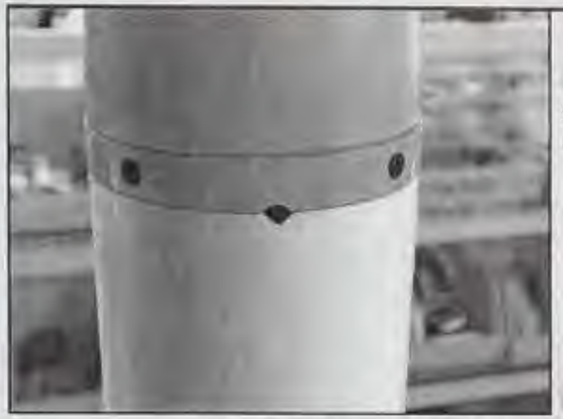


INSTRUCTIONS 32

Coil up the shock cord from the nosecone on top of the parachute.

OPTIONS

Depending on how you folded the parachute, you may need to unwrap the shroud lines, fold it in half again and then re-wrap it so the parachute fits in the rocket body with enough room for the nosecone.



INSTRUCTIONS 33

Slip the nosecone into the rocket body. Twist the nosecone until the center line notches line up.

WHY?

When the center line notch on the upper rocket body and nosecone are aligned, the nosecone will sit perfectly square against the rocket body.



INSTRUCTIONS 34

Put a piece of tape around the nosecone base.

MATERIALS

Masking tape.

WHY?

It's possible for the nosecone to slip out while the rocket is being transported. A piece of masking tape will secure the nosecone to the rocket until it's ready to be launched.



CHAPTER 9

MAKING THE NOZZLE AND ENGINE CASING

The nozzle for the K500 engine is constructed from a PVC coupling, hydraulic cement and a thick steel washer. There are threaded inserts on the nozzle to hold the engine firmly inside the rocket body. Even though the nozzle is simple and inexpensive to build, it doesn't skimp on performance.



01

INSTRUCTIONS

Purchase the following parts:
- One 2" PVC coupling.
- One thick steel washer .906" ID.

MATERIALS

One schedule 40 2" PVC couplings.
One thick steel washer .906" ID x 1.75" OD .17" thick.

WEB

www.homedepot.com part number 232750.
www.mcmaster.com part number 98029A037.



02

INSTRUCTIONS

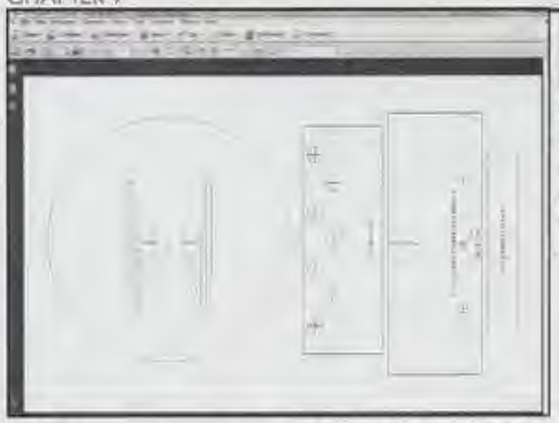
Purchase the following part:
- One 2" schedule 40 PVC pipe x 10'.

MATERIALS

2" Schedule 40 PVC pipe x 10'.

WEB

www.homedepot.com part number 754826.



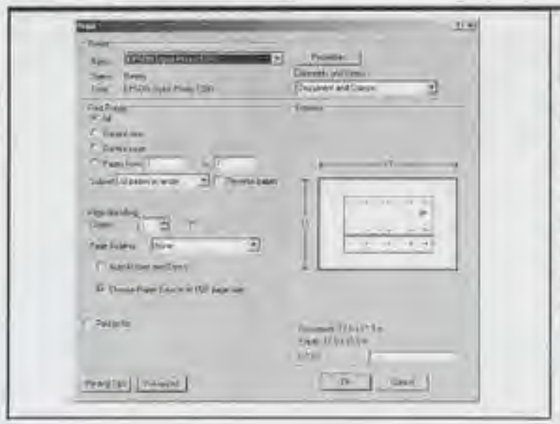
INSTRUCTIONS 03

Download and print out the template:
• *Nozzle Templates 11x17*
The templates will need to be printed on 11x17 paper. If you printer doesn't print that size, copies can usually be made at a copy store or office supply store for a nominal fee.

MATERIALS Printer that can handle 11x17 paper.
Adobe Acrobat reader. Download free at www.adobe.com

PRINT Templates can be found at www.inverseengineering.com under the *templates* tab.

WHY? Having pre-printed templates takes all the guess work out of measuring where holes should be drilled. Spacing is perfect every time.



INSTRUCTIONS 04

It is very important when printing out templates that the *scaling* drop down menu on the print dialog box be set to *None*.
This will ensure that the templates are printed out at 100% size, and all the measurements will be correct. If you ever have trouble with a template not fitting around a piece of pipe, check the scaling dialog box first.



INSTRUCTIONS 05

Cut out the template marked *Coupling Insert*. Leave a little extra space on the top and bottom of the template when cutting it out.

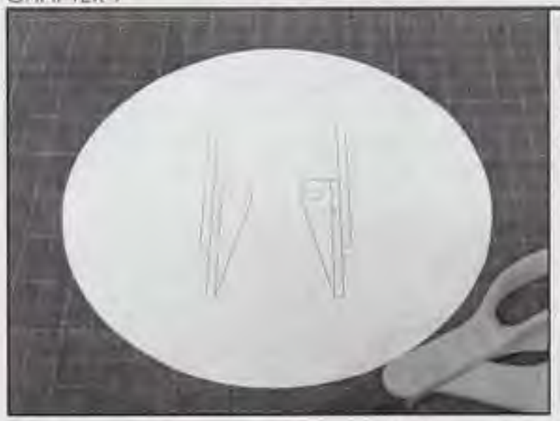
MATERIALS Razor blade or scissors.



INSTRUCTIONS 06

Cut out the 2" *PVC Coupling Retaining Bolt Template* and the *Nozzle Throat Template*.

MATERIALS Razor blade or scissors.



INSTRUCTIONS 07

Cut out the round *Nozzle Template* as accurately as possible.



MATERIALS

Razor blade or scissors.



INSTRUCTIONS 08

Cut the red radius line on the *Nozzle Template* that runs from the center of the drawing to the edge.



MATERIALS

Razor blade or scissors.

WHY?

The cut away drawing of the nozzle on the *Nozzle Template* is there for reference.



INSTRUCTIONS 09

Using an electric miter saw, cut a 1/2" section of 2" PVC pipe.



OPTIONS

A pipe cutter can be used in place of an electric miter saw.

WHY?

This small piece of 2" PVC will be used to form the nozzle mold.



INSTRUCTIONS 10

Roll the *Nozzle Template* in your hand to form a cone. Try to keep the paper along the base of the cone as even as possible.



INSTRUCTIONS 11

Put the paper cone inside the 2" pipe section. The diameter of the bottom of the cone must be equal to the inside diameter of the 2" pipe.



INSTRUCTIONS 12

Release the paper cone inside the 2" pipe section so the cone unwinds.



INSTRUCTIONS 13

Put a small piece of scotch tape on the seam of the paper cone to seal it in place. Remove the cone from the 2" pipe section. Put the 2" pipe section aside for now.

MATERIALS

Scotch tape



INSTRUCTIONS 14

Starting at the seam, lay long pieces of scotch tape along the side of the cone. Overlap the pieces of tape, covering all the paper. It's not necessary to have the tape go up to the top of the cone. About 1/2" to 3/4" below the top is fine.

MATERIALS

Scotch tape.

WHY?

Covering the paper cone with scotch tape will prevent the water based hydraulic cement from soaking into the paper and will also prevent the cement from sticking to the cone.



INSTRUCTIONS 15

Continue to lay long strips of scotch tape around the cone until the cone is completely covered.

MATERIALS Scotch tape.

WHY? Covering the paper cone with scotch tape will prevent the water based hydraulic cement from soaking into the paper and will also prevent the cement from sticking to the cone.



INSTRUCTIONS 16

Trim the pieces of tape off the bottom of the paper cone with a pair of scissors. Put the cone aside for now.

MATERIALS Razor blade or scissors.



INSTRUCTIONS 17

Tape one end of the *Coupling Insert Template* to a section of 2" PVC pipe.

MATERIALS Scotch tape.

WHY? The holes in the coupling insert will give the hydraulic cement something to hold on to.



INSTRUCTIONS 18

Fold the template around the pipe and tape it together. Make sure the lines on either edge of the template line up with each other when you wrap it around the pipe.
Tape over each circle on the template edge and along the edge where the two ends of the template meet.
Tape the top and bottom of the template to the pipe.

MATERIALS Scotch tape.

WHY? There is a half circle on both sides of the template edges. They are there to help you line up the template correctly. The circles on the template need to be taped so that when the template is drilled the paper won't rip.

WHY? The template needs to be securely attached to the pipe so it won't move during drilling.



INSTRUCTIONS 19

Using a 1/2" forstner bit and a drill press, drill out all eight 1/2" holes on the template.

OPTIONS A cordless drill can be used in place of a drill press.

WHY? The holes in the coupling insert will give the hydraulic cement something to hold on to.

WEB More information about forstner bits can be found at www.wikipedia.org under *drill bits*.



INSTRUCTIONS 20

Using an electric miter saw, cut off the top section of pipe above the template.

OPTIONS A pipe cutter or hacksaw can be used in place of the electric miter saw but be careful not to rip the template in the process.



INSTRUCTIONS 21

Using an electric miter saw, cut out the coupling insert from the section of pipe.

OPTIONS A pipe cutter or hacksaw can be used in place of the electric miter saw but be careful not to rip the template in the process.



INSTRUCTIONS 22

Remove the template and any tape. The completed coupling insert should look like this.



INSTRUCTIONS 23

Apply PVC glue to the top half of the coupling insert.

MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 24

Slip the coupling insert into a 2" PVC coupling. Wipe off any excess glue.

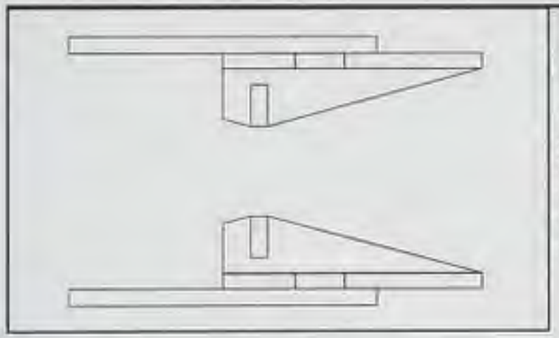


INSTRUCTIONS 25

Tape the *Coupling Retaining Bolt Template* to the nozzle assembly.
It's important that the holes on the *Coupling Retaining Bolt Template* line up with a solid piece of 2" pipe underneath them. Position the template so the holes on the template are NOT over a 1/2" hole on the 2" pipe.
See the picture in step #28 for clarification.

MATERIALS Scotch tape.

WHY? Inexpensive threaded inserts will be inserted into the holes drilled from this template. The threaded inserts will be used to hold the engine inside the rocket body.



INSTRUCTIONS 26

Make sure the side of the template marked *Nozzle End* is on the side of the coupling facing the 2" PVC nozzle insert. In this drawing of the finished nozzle, you can see that the divergent section of the nozzle is the section with the 2" PVC nozzle insert.

WEB For more information on convergent divergent nozzle design, see *de Laval nozzle* at www.wikipedia.org



INSTRUCTIONS 27

Fold the template around the pipe and tape it together. Make sure the lines on either edge of the template line up with each other when you wrap it around the pipe.
Tape over each circle on the template.

MATERIALS Scotch tape.

WHY? There is a half circle on both sides of the template edges. They are there to help you line up the template correctly. The circles on the template need to be taped so that when the template is drilled the paper won't rip.

WHY? The template needs to be securely attached to the pipe so it won't move during drilling.



INSTRUCTIONS 28

In this picture you can see how the holes on the template line up with the space IN BETWEEN the second row of 1/2" holes on the 2" pipe.
Using a 5/16" drill bit and a drill press, drill out all four 5/16" holes on the template.

WHY? Inexpensive threaded inserts will be inserted into the holes drilled from this template. The threaded inserts will be used to hold the engine inside the rocket body.



INSTRUCTIONS 29

Put the nozzle assembly in a drill press vise. Using a carpenter's square, make sure the holes are drilled perpendicular to the drill press vise.
Four lines have been added to the template to assist you with this.

WHY? It's important that the threaded inserts that hold the engine in the rocket body be perpendicular to the nozzle. This way when the engine is installed in the rocket body, everything will fit correctly.



INSTRUCTIONS 30

Drill out all four holes on the template with a 5/16" drill bit.

OPTIONS A cordless drill can be used in place of the drill press as long as the holes are drilled perpendicular to the nozzle assembly.



INSTRUCTIONS 31

Remove the template from the nozzle assembly.
The nozzle assembly should now look like this.



INSTRUCTIONS 32

Purchase the following part:
- Four 1/4-20 brass threaded inserts.

MATERIALS

Four 1/4-20 brass threaded inserts.

WEB

www.mcmaster.com part number 92395A116.



INSTRUCTIONS 33

Put one threaded insert in one of the four holes on the side of the nozzle assembly. You should be able to get the insert started in the hole.
Using a drill press vise, push the threaded insert the rest of the way into the hole.

WHY?

Make sure to put the split end of the threaded insert into the hole first.

WHY?

These brass threaded inserts are inexpensive enough to be used on a single use engine. About $1.50 per engine.



INSTRUCTIONS 34

Continue to pressing inserts into all four holes on the side of the nozzle assembly.
The threaded inserts should be flush with the edge of the nozzle assembly and look like this.



INSTRUCTIONS 35

Purchase the following part:
- Four 1/4-20 x 5/8" button head hex screws.

MATERIALS Four 1/4-20 x 5/8" button head hex screws.

WHY? These four screws will serve two purposes. They will keep the hydraulic cement out of the threaded inserts while the nozzle is drying and they will secure the engine to the rocket body.

WEB www.mcmaster.com part number 91255A539.



INSTRUCTIONS 36

Using a 5/32" hex key or 5/32" hex bit, thread the 1/4-20 x 5/8" hex screws into the four threaded inserts until the tip of the screw is flush with the edge of the threaded insert inside the nozzle assembly.

WHY? These four screws will serve two purposes. They will keep the hydraulic cement out of the threaded inserts while the nozzle is drying and they will secure the engine to the rocket body.



INSTRUCTIONS 37

Place a thick steel .906" ID washer on your work surface.



INSTRUCTIONS 38

Roll up the *Nozzle Throat Template* and put it inside the steel washer.

WHY? The *Nozzle Throat Template* will form a throat in the hydraulic cement. Using a template like this will reduce the amount of drilling required when the cement is dry.



INSTRUCTIONS 39

Let the template un-roll inside the washer then put a piece of scotch tape on the seam to hold it in place.

MATERIALS

Scotch tape.



INSTRUCTIONS 40

Remove the *Nozzle Throat Template* from the washer and cover the bottom of the template roll with scotch tape.

MATERIALS

Scotch tape.

WHY?

Covering the template with scotch tape will prevent the water based hydraulic cement from soaking into the paper and will also prevent the cement from sticking to the template.



INSTRUCTIONS 41

Put the cone from step #16 on your work surface.



INSTRUCTIONS 42

Put the nozzle assembly over the paper cone. The paper cone should be the exact size of the of the inside of the 2" pipe. Press the nozzle assembly down so it is flush with the work surface.



INSTRUCTIONS 43

Gently put a thick steel washer on top of the paper cone. Adjust the washer so it sits flat and snug against the paper cone.

WHY? The thick steel washer will prevent the nozzle throat from eroding when the engine burns. This will greatly increase the efficiency and power output of the engine.



INSTRUCTIONS 44

Put the *Nozzle Throat Template* over the cone. The template should sit over the cone, inside the washer.

WHY? The *Nozzle Throat Template* will form a throat in the hydraulic cement. Using a template like this will reduce the amount of drilling required when the cement is dry.



INSTRUCTIONS 45

Purchase the following part:
• *Rocktite* hydraulic anchoring cement.

Measure out 1 1/2 level cups of hydraulic anchoring cement into a *Ziploc* bag.

MATERIALS *Rocktite* hydraulic anchoring cement 5 lb. box.
Ziploc quart size bags.

OPTIONS Any type of hydraulic cement will work. Just make sure the cement EXPANDS as it dries otherwise the nozzle will not form a tight seal against the PVC.

WEB www.mcmaster.com part number 7569T92.



INSTRUCTIONS 46

Add 1/2 cup clean water to the hydraulic cement. Close the *Ziploc* bag and mix the cement by kneading the bag until the cement mixture is smooth.

WHY? The ratio of 1 1/2 cups cement to 1/2 cup water will make three nozzles. I always make more than one engine at a time so this mixture works for me. If you're only going to make one engine just ratio it down.



47 INSTRUCTIONS

Once the cement mixture is smooth, cut a corner off the *Ziploc* bag and pour the mixture into a plastic cup.

MATERIALS

Disposable plastic cup.



48 INSTRUCTIONS

Fill a plastic syringe with the hydraulic cement. The plastic syringe is OPTIONAL. The cement can be poured directly from the *Ziploc* bag or plastic cup.

MATERIALS

50cc Plastic syringe.

OPTIONS

Using a plastic syringe is convenient but not necessary. Pouring the cement directly from the *Ziploc* bag might be a little messy but will get the job done.

WEB

www.mcmaster.com part number 7510A665.



49 INSTRUCTIONS

Slowly pour the cement into the nozzle mold. Read step #46 before proceeding with this step.

WHY?

The cement needs to be poured into the nozzle mold slowly so that air can escape, especially around the 1/2" holes on the coupling insert.



50 INSTRUCTIONS

There's a thin lip around the inside of the PVC coupling. This *stop* prevents pipe from being inserted more than half way into the coupling. You want to fill the nozzle mold with cement until it JUST COVERS the *stop*.



INSTRUCTIONS 51

If a little cement leaks out the bottom, don't worry. Just add a little more to top it off and make sure that the cement level is JUST ABOVE the coupling *stop*.
Let the cement dry for 30 minutes.
Clean the plastic syringe with clean water so it can be used again.



INSTRUCTIONS 52

Once the cement has dried, remove the paper cone and discard it.



INSTRUCTIONS 53

Remove the throat template and discard it.



INSTRUCTIONS 54

Let the nozzle dry on its side overnight.

WHY? Placing the nozzle on its side will allow air to flow through the nozzle and prevent condensation from forming.



INSTRUCTIONS 55

Using a variable diameter drill bit, cut a chamfer in the convergent section of the nozzle. Drill down until the drill bit hits the thick steel washer.
This is the same bit that was used in chapter 6. step #27.



OPTIONS A round file can be used in place of the multi-diameter drill bit.

WHY? The purpose of the chamfer is to compress hot combustion gasses as they enter the nozzle throat. It will also guide the coring rod into the throat when the fuel is being cast.

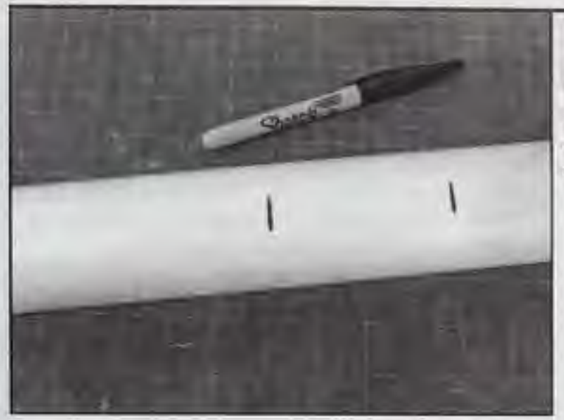
WEB www.mcmaster.com part number 8910A14.
Unfortunately this tool is expensive but it does a fantastic job.



INSTRUCTIONS 56

The finished nozzle should look like this.

WHY? The purpose of the chamfer is to compress hot combustion gasses as they enter the nozzle throat. It will also guide the coring rod into the throat when the fuel is being cast.



INSTRUCTIONS 57

Using a black *Sharpie* marker, make two marks on a section of 2" PVC pipe. One at 31 3/4" and the other at 35"

MATERIALS Black *Sharpie* or similar permanent marker.

WHY? One mark will be used to cut the pipe now, the other will be used to trim it once the fuel has been cast in the engine.



INSTRUCTIONS 58

Using an electric miter saw, cut the pipe at the 35" mark.



INSTRUCTIONS

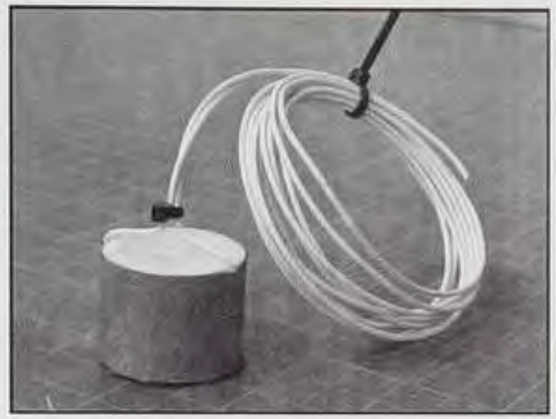
59

Using PVC glue, attach the 2" pipe to the nozzle assembly. Make sure the pipe goes all the way inside the coupling. Wipe up any excess glue. Glue the end of the pipe to the nozzle WITHOUT the measurement marks from step #53. Those should be on the opposite end.

MATERIALS

I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.





CHAPTER 10

MAKING THE ENGINE IGNITER

The K500 engine igniter is specifically designed to be part of the engine. The igniter sits on top of the fuel grain and is incased in the smoke element. Easy and inexpensive to make, the engine igniter is one of the most reliable ways to ignite the engine.



INSTRUCTIONS 01

Purchase the following part:
• 1" PVC pipe 2' long.

Using an electric miter saw, cut a 1" length of 1" pipe.

MATERIALS

1" Schedule 40 PVC pipe 2' long.

WHY?

Schedule 40 PVC pipe and fittings are readily available, affordable and easy to work with.

WEB

Home Depot part number 193755 or similar.



INSTRUCTIONS 02

Drill two 1/16" holes on opposite sides of the 1" pipe about 1/8" down from the top.



03

INSTRUCTIONS

Purchase the following part:
• One small spool of 32 gauge nichrome wire.

Using a pair of wire cutters, cut an 8" length of nichrome wire.

The nichrome wire spool used in this step is also used in chapter 6.

MATERIALS

Nickel Chromium wire 32 gauge, 0.008" diameter, 1/8 lb. spool.

WHY?

Also known as Nichrome, nickel chromium is a very temperature resistant wire. It is often used for heating elements, resistance windings and hot wire cutters.

WEB

www.mcmaster.com part number 8880K83.



04

INSTRUCTIONS

Purchase the following part:
• One roll stranded single conductor wire.

Cut two 48" lengths of 22 gauge stranded wire.

MATERIALS

One roll stranded single conductor wire 22 AWG - white.

WHY?

The wires needs to be 48" long because the igniter will sit in the top of the engine and the ignition wires will go down the length of the engine.

WEB

www.mcmaster.com part number 7587K325.



05

INSTRUCTIONS

Strip 3/4" insulation off the end of each wire.



06

INSTRUCTIONS

Split the strands into a *V* on one of the 18" wires.

WHY?

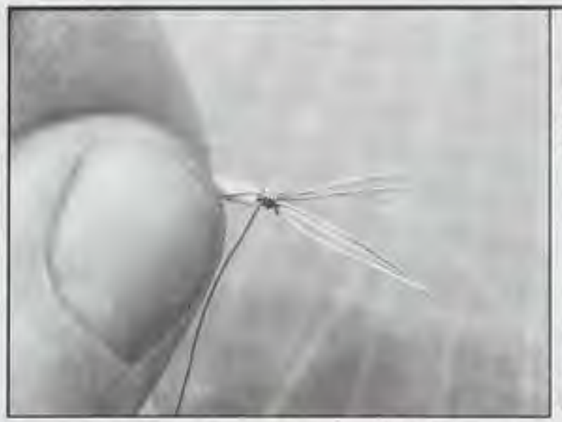
The nichrome wire will be used to light the pyrogen that will ignite the fuel in the engine. It's not possible to solder nichrome wire so looping it between strands of 22 gauge wire and then twisting them tight is an excellent way to ensure the igniter works consistently.



INSTRUCTIONS 07

Hold the length of nichrome wire between your thumb and index finger and run it between the split strands of 22 gauge wire.

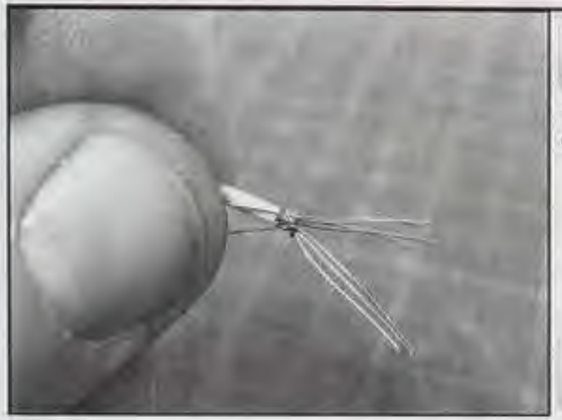
WHY? The nichrome wire will be used to light the pyrogen that will ignite the fuel in the engine. It's not possible to solder nichrome wire so looping it between strands of 22 gauge wire and then twisting them tight is an excellent way to ensure the igniter works consistently.



INSTRUCTIONS 08

Wrap the nichrome wire around the base of the 22 gauge wire 8 times.

WHY? Wrapping the nichrome wire several times around the base of the 22 gauge wire will ensure they maintain good contact with each other.



INSTRUCTIONS 09

Run the nichrome wire between the split strands one more time.



INSTRUCTIONS 10

Twist the strands together then, using a pair of needle nose pliers, twist the strands one or two more times to make sure they are good and tight.

WHY? Twisting the strands locks the nichrome wire in place.



INSTRUCTIONS 11

Trim the 22 gauge strands to 3/8".

WHY? The nichrome wire is now locked in the strands of the 22 gauge wire.



INSTRUCTIONS 12

Thread the nichrome wire through the two 1/16" holes on the 1" pipe.



INSTRUCTIONS 13

Split the strands on the second piece of 22 gauge wire and repeat steps 6 through 11.
Leave about 1" nichrome wire between the 22 gauge wire and the 1" pipe.

WHY? Twisting the strands locks the nichrome wire in place.



INSTRUCTIONS 14

Start rolling up the extra nichrome wire by twisting the 22 gauge wire between your thumb and fore-finger, wrapping the nichrome wire around the wire strands.

WHY? You want the nichrome wire that's inside the 1" pipe to be tight but still give a little when you press on it.



INSTRUCTIONS 15

You should now have a piece of 22 gauge wire on either side of the 1" pipe with a nichrome wire stretched between them.



INSTRUCTIONS 16

While holding the two 22 gauge wires in place, wrap a piece of scotch tape around the top of the 1" pipe so the wires are held in place.

MATERIALS Scotch tape.

WHY? The tape will hold the wires in place and will also prevent any pyrogen from leaking out the 1/16" holes when the igniter is filled.



INSTRUCTIONS 17

Put the 1" pipe on its side and gently bend over the excess strands of wire. Repeat with the other 22 gauge wire.

WHY? The ends of the 22 gauge wire strands are sharp and will poke through the top of the igniter if not bent over.



INSTRUCTIONS 18

The 1" pipe should now look like this. Put it aside for now.



19 INSTRUCTIONS

Put a 6" length of 2" wide masking tape on your work surface.

MATERIALS 2" Wide masking tape or similar.

WHY? When the igniter is lit, the hot gasses will have to push through this piece of tape. The masking tape is strong enough to hold the igniter together but weak enough to prevent the hot gasses from building up and damaging the engine.



20 INSTRUCTIONS

Using the small 2" pipe piece cut in chapter 9 and a black *Sharpie* marker, draw a circle on the tape using the inside of the pipe as a guide.

MATERIALS Black *Sharpie* or similar permanent marker.
2" Pipe piece from chapter 9.



21 INSTRUCTIONS

Cut the circle out from the masking tape.

MATERIALS Razor blade or scissors.



22 INSTRUCTIONS

Put the masking tape circle down on your work surface, STICKY SIDE UP. Hold the tape circle in place with one finger and press the 1" PVC pipe down on it. Put the side with the nichrome wire down on the tape.

WHY? The masking tape circle will for the bottom of the igniter that will eventually sit on top of the fuel grain in the engine.



INSTRUCTIONS 23

Turn the 1" pipe over and hold it between your fingers.



INSTRUCTIONS 24

Fold over two edges of tape on top of the 22 gauge wires.



INSTRUCTIONS 25

Fold over two edges of tape 90 degrees from the 22 gauge wires.



INSTRUCTIONS 26

Fold over the last four edges of tape so that the tape circle is now neatly covering the opening of the 1" pipe.



INSTRUCTIONS 27

Wrap a layer of 1" wide masking tape around the side of the 1" pipe.

MATERIALS

1" Wide masking tape or similar.

WHY?

The 22 gauge wires should now be firmly held on the side of the 1" pipe.



INSTRUCTIONS 28

Put the igniter on your work surface, open end up. Bend the two 22 gauge wires slightly to the side.

WHY?

Bending the wires to the side will make filling the igniter easier.



INSTRUCTIONS 29

Fill the igniter halfway with the pyrogen mix made in chapter 6.

MATERIALS

Pyrogen mix made in chapter 6.

WHY?

The nichrome wire will heat up when current is put through it. The hot wire will ignite the pyrogen which burn down the core of the engine, igniting the fuel.



INSTRUCTIONS 30

GENTLY press the pyrogen down in the igniter with your finger. You want to tap it down gently at first to avoid damaging the nichrome wire. Once the pyrogen is firmly in place around the nichrome wire you can press a little harder to pack it down.

WHY?

Unlike the parachute piston in chapter 6, the pyrogen in the igniter will be packed. It doesn't take much pressure to compact the powder into a semi-solid.

WHY?

If the pyrogen was left in powder form it would burn all at once. For the parachute piston that's exactly what we want but for the igniter, a long, steady burn will be better.



INSTRUCTIONS 31

Add more pyrogen to the igniter.

WHY? You will achieve a more consistant, uniform semi-solid if the pyrogen is packed in layers.



INSTRUCTIONS 32

Pack the pyrogen down with your finger. Just a little pressure with your finger will compact the pyrogen.



INSTRUCTIONS 33

Add more pyrogen to the igniter.



INSTRUCTIONS 34

Using the back of a 1/2 teaspoon measuring spoon, press the pyrogen down while twisting the spoon to make a concave indentation in the top of the pyrogen.
You may need to add more pyrogen one or two more times until the igniter is full and will not take any more pyrogen.

OPTIONS A regular metal spoon can be used in place of the 1/2 teaspoon measuring spoon.

WHY? The 1/2 teaspoon measuring spoon will leave a nice concave indentation on the top layer of pyrogen. This will allow epoxy to form a seal to the igniter.



INSTRUCTIONS 35

Once the igniter is full, it should look like this, with a smooth concave indentation on the top.



INSTRUCTIONS 36

Gently knock off any loose pyrogen from the top and sides of the igniter.

WHY? The top of the igniter needs to be clean so the epoxy will stick to it.



INSTRUCTIONS 37

Fill the concave indentation on the top of the igniter with a fast setting two part epoxy.

MATERIALS
Loctite E-00CL fast setting epoxy.
Loctite applicator gun.
Loctite mixing nozzle.

OPTIONS A less expensive two part epoxy can definetly be substituted for the epoxy in this step. The gun and mixing nozzle just make it easier.

WEB
www.mcmaster.com part number 6430A16.
www.mcmaster.com part number 74695A71.
www.mcmaster.com part number 74695A12.



INSTRUCTIONS 38

Using a wooden skewer, *pull* the epoxy over to the edges of the igniter. You want the entire top of the igniter to be covered with epoxy.

MATERIALS Wooden skewer, toothpick or other disposable mixing stick.

WHY? *Pulling* the epoxy over to the edge of the igniter will give the epoxy something solid to adhere to other than the pyrogen.



INSTRUCTIONS 39

Let the epoxy harden throughly.



INSTRUCTIONS 40

Pinch the two 22 gauge wires together on the top of the igniter.





WHY? Securing the two 22 gauge wires together will prevent any damage to the igniter from rough handling.



INSTRUCTIONS 41

Put a small zip tie around the two igniter wires to hold them together.



MATERIALS Small zip tie.

WEB www.mcmaster.com part number 7130K52.



INSTRUCTIONS 42

Strip 1/4" insulation off both ends of the igniter wires.





INSTRUCTIONS 43

Run a continuity test on the igniter wires. The result should be between 1.4 and 1.6 Ohms.

WHY? It's always good to test the igniter to make sure there were no mistakes made during its construction.

WEB More information about Ohms and continuity can be found at www.wikipedia.org under ohm.



INSTRUCTIONS 44

Cut off the two stripped ends on the igniter wires. Wrap up the igniter wires and secure them with a small zip tie. The igniter is now completed and will be used later in chapter 12.

WHY? Cutting the stripped ends of the 22 gauge wires will reduce the possibility of accidental ignition.

WHY? A 9 to 18 volt current through the igniter wires is all it takes to light the igniter.

WEB www.mcmaster.com part number 7130K52.





CHAPTER 11

MAKING AND CASTING THE FUEL

Read the next two chapters all the way through before starting the fuel. While casting the fuel is a relatively simple procedure, you need to have all the tools and materials on hand before starting. Make sure you have a fire extinguisher close by during this chapter and the next. A fire extinguisher should be a permanent fixture in your shop anyway.



INSTRUCTIONS 01

Purchase the following parts:
- 1" PVC pipe 2' long.
- One 2" PVC coupling.
- One 2" x 1" PVC bushing.

Cut a 12" section of 1" PVC pipe and set it aside.

MATERIALS

1" Schedule 40 PVC pipe 2' long.
2" PVC coupling.
2" x 1" PVC bushing.

WHY?

Schedule 40 PVC pipe and fittings are readily available, affordable and easy to work with.

WEB

Home Depot part number 254997 or similar.
Home Depot part number 232750 or similar.
Home Depot part number 544404 or similar.



INSTRUCTIONS 02

Using PVC glue, attach the 2" x 1" bushing to the 2" coupling.

MATERIALS

I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 03

Put the 2" coupling in a drill press vise, bushing side down. Tighten the vise so the coupling is firmly in place.



WHY? The engine core guide needs to be able to slip on and off the engine casing.



INSTRUCTIONS 04

Using a 2 3/8" hole saw without an arbor bit, drill down through the coupling and into the plastic stop. The hole saw should fit exactly inside the coupling and shouldn't take much plastic off at all.



OPTIONS A *Dremel* tool with an abrasive bit or a round bastard file can be used in place of a hole saw.

WHY? Why the hearing protection icon? For some reason the hole saw makes a lot of noise.



INSTRUCTIONS 05

Place the coupling on a scrap piece of 2" PVC to make sure it fits correctly. The coupling should slip on and off the pipe easily and there shouldn't be too much play between the coupling and the pipe.

WHY? The engine core guide needs to be able to slip on and off the engine casing.



INSTRUCTIONS 06

Using PVC glue, attach the 12" section of 1" pipe to the 2" x 1" bushing.



MATERIALS I use *Christy's Red Hat PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 07

Purchase the following part:
1" x 6' Aluminum rod

Cut the 6' aluminum rod down to 50".

MATERIALS

1" x 6' Aluminum rod - alloy 6061.

OPTIONS

Any type of metal rod will work for the engine coring rod. Just make sure the rod is 1" in diameter and has a smooth surface.

WEB

www.mcmaster.com part number 8974K37.



INSTRUCTIONS 08

Using a bench mounted grinder, grind down one end of the aluminum rod until it's rounded.

WHY?

The coring rod will travel through the center of the fuel and line up with the nozzle throat. This is imperative for making the engine work properly.



INSTRUCTIONS 09

Measure out about 4 pounds of potassium nitrate in a 12" x 12" metal pan.

MATERIALS

Granular or prilled potassium nitrate, Kno3.
Keep away from laboratory grade potassium nitrate as the high purity is not necessary and the price is too high. Agricultural grade potassium nitrate will work just fine.

OPTIONS

Granular potassium nitrate can be used as is. Prilled potassium nitrate is in the form of little balls. As long as these balls are not coated in clay, the prills can be ground down in a coffee grinder and used as granular potassium nitrate.

WEB

Many sources online supply potassium nitrate in various forms and weights. A quick Google search will turn up several suppliers.



INSTRUCTIONS 10

Heat the potassium nitrate in a toaster oven for 30 minutes at 300 degrees.

WHY?

Never mix anything with the potassium nitrate before it is heated. Only heat the potassium nitrate by itself.

WHY?

Potassium nitrate is hygroscopic, meaning it will absorb moisture from the air. Heating it at 300 degrees for 30 minutes will drive out all the moisture.

WEB

More information about potassium nitrate can be found at www.wikipedia.org under Kno3.



INSTRUCTIONS 11

While the potassium nitrate is in the toaster oven, start laying out items that will be used to make the fuel.
Put a 12" x 12" rubber pad near one end of the table.

OPTIONS A damp towel can be used in place of a rubber pad.

WHY? Stirring the wok with thick fuel in it has the tendency to spin the wok on the table. A rubber pad will prevent this.

WEB www.mcmaster.com part number 8635K464.



INSTRUCTIONS 12

Lay out two layers of paper towels and set the aluminum coring rod on top of them. Place the rod on the towels so the rounded end is on the right and the blunt end hangs over the edge of the table.

WHY? The paper towels will absorb excess WD-40 that is sprayed on the rod.



INSTRUCTIONS 13

Put a 5 gallon plastic bucket half filled with clean water on the floor near the table.



INSTRUCTIONS 14

Put the following items on the table:
- A wooden spoon
- Work gloves
- A potato masher
- WD-40 or similar lubricant

WEB www.mcmaster.com part number 1347K17 (WD-40)



INSTRUCTIONS 15

Put the following items on the table:
- Wide mouth plastic funnel
- A stiff bristle scrub brush

WEB www.mcmaster.com part number 9017T15 (wide mouth funnel)



INSTRUCTIONS 16

Spray a little WD-40 on the coring rod and clean it off with a paper towel. Lay the coring rod back down on the paper towels and coat the rod liberally with WD-40.

WHY? WD-40 lubricant will allow the coring rod to slide out of the engine once the fuel has hardened around it.



INSTRUCTIONS 17

Set the engine casing from chapter 9, nozzle end down on the floor.



INSTRUCTIONS 18

Take a sheet of 8 1/2" x 11" paper and trace a circle on the inside of a small piece of 2" pipe.

MATERIALS Black *Sharpie* or similar permanent marker.



INSTRUCTIONS 19

Cut out the paper circle.

MATERIALS

Razor blade or scissors.

INSTRUCTIONS 20

Drop the paper circle in the engine casing. It will fall down the pipe and settle on the top of the nozzle throat.

WHY?

The paper circle will prevent hot fuel from spilling out the nozzle. The coring rod will pierce the paper circle when it's pushed through the hot fuel.



INSTRUCTIONS 21

Put a plastic wide mouth funnel on top of the engine casing.

WHY?

A wide mouth funnel will make it easier to pour the hot fuel into the engine casing.

WHY?

It's important that a wide mouth funnel be used instead of a regular funnel. The fuel will clog up the narrow throat of a regular sized funnel.



INSTRUCTIONS 22

Place the coring guide made at the beginning of this chapter on the table near the coring rod.

WHY?

The coring guide will ensure that the coring rod travels through the center of the fuel and lines up with the nozzle throat. This is imperative for making the engine work properly.



INSTRUCTIONS 23

Place the following on the table:
- A pair of channel lock pliers.
- A digital infrared thermometer (see step #24).

WHY? It's important that the temperature of the fuel doesn't exceed 210 degrees. The moisture from the corn syrup is what makes the fuel flexible. If the fuel gets hotter than 210 degrees, the moisture will start to evaporate.



INSTRUCTIONS 24

An inexpensive option to an infrared thermometer is a sheet of one time use single point temperature indicating labels. These small labels can be attached to the front or back of a wooden spoon that is used to stir the fuel. Once the correct temperature is reached, the dot on the label turns black.

WEB www.mcmaster.com part number 5952K223.



INSTRUCTIONS 25

Put an electric wok on a digital scale and measure out 0.89 pounds of corn syrup.

OPTIONS Depending on the type of scale you have, you may need to put something hard and flat underneath wok so it will sit squarely on the scale.

WHY? Make sure you zero out the scale before adding the corn syrup.

WHY? Digital scales vary in quality and cost. An inexpensive scale can be found online with a little searching. The scale must have a resolution of 1/100th of a pound.



INSTRUCTIONS 26

Place the electric wok with the corn syrup on the table.



INSTRUCTIONS 27

Put a plastic container on a digital scale and measure out 0.94 pounds of powdered sugar.

MATERIALS

Plastic container.

WHY?

Make sure you zero out the scale before adding the powdered sugar.



INSTRUCTIONS 28

By this time the potassium nitrate should be finished drying in the toaster oven. Remove the metal pan and place it on a stable work surface. The metal pan will be HOT.



INSTRUCTIONS 29

Using a potato masher, break up any lumps of potassium nitrate in the metal dish. Don't worry if there are some small lumps left over, they will break down during the next few steps.

WHY?

The potassium nitrate has a tendency to cake together when it is dried in the toaster oven. A potato masher will break the lumps apart.



INSTRUCTIONS 30

Put a mixing bowl from a stand mixer on a digital scale and measure out 3.41 pounds of potassium nitrate from the metal dish in step #29.

OPTIONS

If you're not using a stand mixer, just mix the potassium nitrate and powdered sugar with a hand mixer on the lowest speed or spoon for about 5 minutes until it's throughly mixed.

OPTIONS

If you don't plan to use a stand mixer, any large mixing bowl will do.



INSTRUCTIONS 31

Put the metal pan with the remaining potassium nitrate back in the toaster oven. Make sure the toaster oven is off.

WHY? Some of the potassium nitrate will be used in the next chapter to make the smoke element.



INSTRUCTIONS 32

Put the mixing bowl with the potassium nitrate back on the stand mixer and add the powdered sugar from step #27.

OPTIONS If you're not using a stand mixer, just mix the potassium nitrate and powdered sugar with a hand mixer on the lowest speed or spoon for about 5 minutes until it's throughly mixed.

WHY? From this point on the mixture is FLAMMABLE.



INSTRUCTIONS 33

Mix the potassium nitrate and powdered sugar on the mixer's lowest speed until it's throughly mixed, about 5 minutes.

OPTIONS If you're not using a stand mixer, just mix the potassium nitrate and powdered sugar with a hand mixer on the lowest speed or spoon for about 5 minutes until it's throughly mixed.



INSTRUCTIONS 34

Put the potassium nitrate sugar mixture on the table next to the wok.

WHY? The potassium nitrate sugar mixture needs to be in a convenient location once the corn syrup heats up.



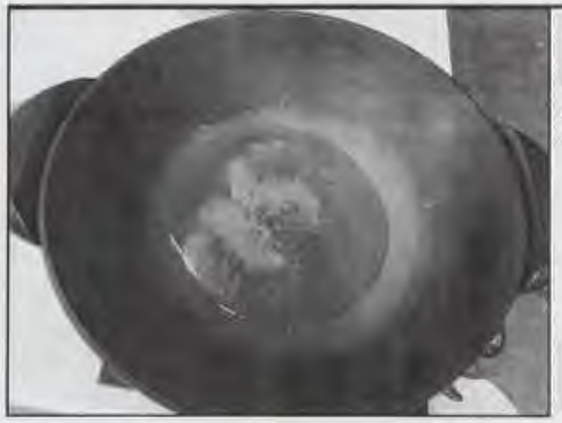
INSTRUCTIONS 35

Plug in the wok and turn the temperature dial to its highest setting.



WHY? The wok needs to be on its highest setting to get the fuel up to temperature as quickly as possible. Remember, heating the fuel is just to lower its viscosity, not to drive out moisture.

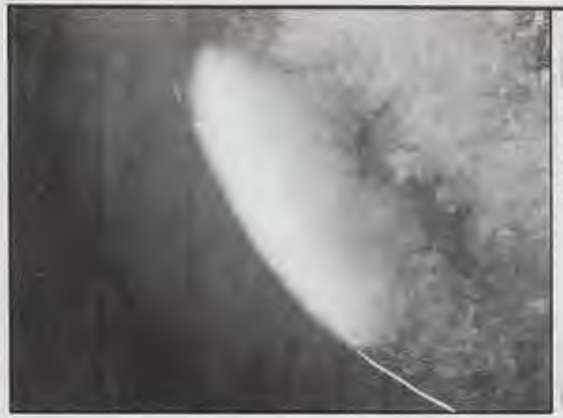
WHY? Viscosity is a measure of the resistance of a fluid. The less viscous the fluid is, the greater its ease of movement.



INSTRUCTIONS 36

As the corn syrup starts to heat up, small bubbles will form on the bottom of the wok.





INSTRUCTIONS 37

Heating the corn syrup should take about 3 minutes depending on the wattage of your wok. Heat the corn syrup until bubbles break the surface of the syrup.





INSTRUCTIONS 38

Add the entire potassium nitrate sugar mixture to the hot corn syrup.





INSTRUCTIONS 39

Immediately start stirring the fuel mixture with a wooden spoon. Start in the center and work your way out.

WHY? Don't stop stirring! Stir the mixture constantly until it reaches 210 degrees.

WHY? Don't use a metal spoon to mix the fuel. The chance of a spark between the metal wok and a metal spoon is slight, but it could happen.



INSTRUCTIONS 40

Incorporate the powder around the edge of the wok into the fuel mixture.

WHY? Don't stop stirring! Stir the mixture constantly until it reaches 210 degrees.

WHY? Don't use a metal spoon to mix the fuel. The chance of a spark between the metal wok and a metal spoon is slight, but it could happen.



INSTRUCTIONS 41

Check the temperature of the fuel mixture regularly. It won't take long to reach 210 degrees. As you stir the fuel, any remaining lumps of potassium nitrate will break down and the mixture will become very smooth.

WHY? Don't stop stirring! Stir the mixture constantly until it reaches 210 degrees.

WHY? Don't use a metal spoon to mix the fuel. The chance of a spark between the metal wok and a metal spoon is slight, but it could happen.



INSTRUCTIONS 42

About 5 to 10 minutes from when you started to heat the fuel mixture, the fuel will become very fluid. Remember, the point of adding heat to the fuel mixture is to lower its viscosity so it will be easier to pour.

WHY? Viscosity is a measure of the resistance of a fluid. The less viscous the fluid is, the greater its ease of movement.

WHY? Don't stop stirring! Stir the mixture constantly until it reaches 210 degrees.

WHY? Don't use a metal spoon to mix the fuel. The chance of a spark between the metal wok and a metal spoon is slight, but it could happen.



INSTRUCTIONS 43

Once the fuel mixture reaches 210 degrees, unplug the wok and immediately pour all the fuel into the engine casing.

WHY? The fuel will start to harden as it cools. So get it into the engine casing as soon as possible.

WHY? Don't use a metal spoon to mix the fuel. The chance of a spark between the metal wok and a metal spoon is slight, but it could happen.



INSTRUCTIONS 44

Set the wok back down on the table.



INSTRUCTIONS 45

Take the plastic funnel off the engine casing and put it into a bucket of water.

WHY? Putting your tools in water is the best way to clean them. The fuel will completely dissolve in water in about 20 minutes.

WHY? I don't have a sink in my shop so this is how I clean my tools. If you have access to a sink, just run your tools under cool water until the fuel dissolves.



INSTRUCTIONS 46

Put the coring guide on top of the engine casing.

WHY? The coring guide will ensure that the coring rod travels through the center of the fuel and lines up with the nozzle throat. This is imperative for making the engine work properly.



INSTRUCTIONS 47

Slip the coring rod gently into the coring rod guide and down into the fuel. Continue to press the rod down into the fuel until it reaches the nozzle. The coring rod is too wide to fit in the nozzle throat but it will sit nicely in the chamfer you cut into the top of the nozzle in chapter 9, step #55. Once the coring rod has reached the nozzle, give it a twist while pushing on it and you should feel it fall into place against the nozzle throat.





INSTRUCTIONS 48

Let the engine and coring rod sit undisturbed for 3 hours.



WHY? As the fuel cools it will harden from a thick liquid to a flexible solid. The corn syrup in the fuel will keep it flexible, it's the primary reason the engine works consistently without failure.



INSTRUCTIONS 49

Fill a platic cup with water and pour it into the wok.



WHY? Putting your tools in water is the best way to clean them. The fuel will completely dissolve in water in about 20 minutes.

WHY? I don't have a sink in my shop so this is how I clean my tools. If you have access to a sink, just run your tools under cool water until the fuel dissolves.



INSTRUCTIONS 50

Plug in the wok and let the water come to a boil.



WHY? The excess fuel will dissolve more quickly in hot water.



51 INSTRUCTIONS

Using a scrub brush, clean off the excess fuel from the wooden spoon



MATERIALS

Stiff scrub brush.



52 INSTRUCTIONS

Put the wooden spoon in the bucket with the plastic funnel.



WHY?

Putting your tools in water is the best way to clean them. The fuel will completely dissolve in water in about 20 minutes.

WHY?

I don't have a sink in my shop so this is how I clean my tools. If you have access to a sink, just run your tools under cool water until the fuel dissolves.



53 INSTRUCTIONS

Using the scrub brush, clean off the excess fuel on the inside of the wok.



WHY?

The excess fuel will dissolve more quickly in hot water.



54 INSTRUCTIONS

Unplug the wok and pour the hot water into the metal mixing bowl.



WHY?

The excess potassium nitrate and powdered sugar in the mixing bowl will get sticky if not cleaned.



INSTRUCTIONS 55

Slosh the water around the mixing bowl and then pour it into the bucket with the plastic funnel and wooden spoon.



INSTRUCTIONS 56

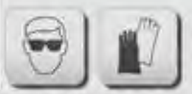
Wipe out the wok with clean paper towels.





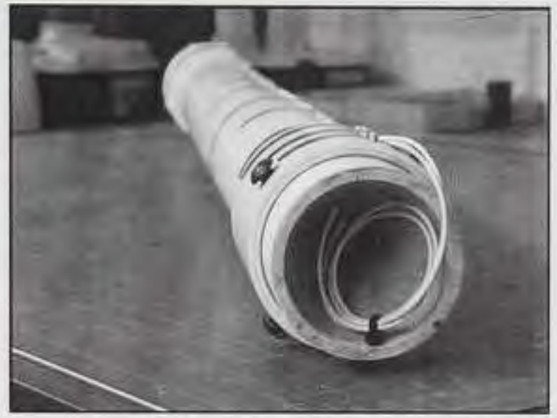
INSTRUCTIONS 57

Wipe out the mixing bowl with clean paper towels. Take the plastic funnel and wooden spoon out of the bucket and wipe them off with paper towels as well.



WHY? Putting your tools in water is the best way to clean them. The fuel will completely dissolve in water in about 20 minutes.

WHY? I don't have a sink in my shop so this is how I clean my tools. If you have access to a sink, just run your tools under cool water until the fuel dissolves.



CHAPTER 12

INSTALLING THE IGNITER, SMOKE ELEMENT AND END CAP

In this chapter, the whole engine comes together. We'll install the igniter from chapter 10 and add a simple smoke element that will allow the rocket's path to be seen several thousand feet away. Then we'll install a cap to hold it all together.



INSTRUCTIONS 01

Purchase the following parts:
- One 2" PVC coupling.
- One 2" x 1" slip bushing.

MATERIALS

One 2" PVC coupling.
One 2" x 1" slip bushing.

WHY?

The coupling will be installed over the engine casing where the smoke element is. The smoke element has a tendency to burn through the engine casing and this coupling prevents that.

WEB

www.homedepot.com part number 232750.
www.homedepot.com part number 544404.



INSTRUCTIONS 02

Put the 2" x 1" bushing into one end of the coupling. DO NOT GLUE THE BUSHING.

WHY?

The bushing will help the coupling hold its shape in the drill press vise.



INSTRUCTIONS 03

Put the coupling in a drill press vise bushing side down. Tighten the vise so the coupling is held firmly in place.



WHY? The coupling needs to be able to slip on the engine casing.



INSTRUCTIONS 04

Using a 2 3/8" hole saw without an arbor bit, drill down through the coupling and into the plastic stop. The hole saw should fit exactly inside the coupling and shouldn't take much plastic off at all.



OPTIONS A *Dremel* tool with an abrasive bit or a round bastard file can be used in place of a hole saw.

WHY? Why the hearing protection icon? For some reason the hole saw makes a lot of noise.



INSTRUCTIONS 05

Put the coupling on a scrap piece of 2" pipe to make sure it slips on and off easily. The coupling should be tight enough to stay in one place but should also be easy to remove.

WHY? The coupling will be installed over the engine casing where the smoke element is. The smoke element has a tendency to burn through the engine casing and this coupling prevents that.



INSTRUCTIONS 06

Purchase the following parts:

- *West Systems* 105-A resin & 205-A hardener.
- One 1/4-20 x 1" button head hex screw.
- One vinyl cap with dome top.

MATERIALS
West Systems 105-A resin & 205-A hardener.
One 1/4-20 x 1" button head hex screw.
One vinyl cap with dome top.

OPTIONS Any two part epoxy will work well for the smoke element. *West Systems* is expensive but works very well. Some experimentation with other brands may yield a cost savings.

WEB
www.mcmaster.com part number 7480A41 & 7480A42.
www.mcmaster.com part number 91255A542.
www.mcmaster.com part number 9343K59.



INSTRUCTIONS 07

Purchase the following part:
• One 2" schedule 40 PVC cap.

There's usually a small circle or nub directly in the center of the cap left over from the manufacturing process. Mark the center of the cap with a center punch.

MATERIALS One 2" schedule 40 PVC cap.

WHY? It's important that the hole in the center of the cap is as accurate as possible.

WEB www.homedepot.com part number 232777.



INSTRUCTIONS 08

Drill a 1/16" hole in the center of the cap on the spot marked with the center punch.

WHY? The next three holes will be drilled from the top of the cap down so a pilot hole is needed to mark the center hole.



INSTRUCTIONS 09

Turn the cap over and place it squarely in a drill press vise. Drill three 7/32 holes in the top of the cap. One in the center as accurately as possible and the other two about 1/4" on either side of the center hole. The exact placement of these holes is not critical.

WHY? A 1/4-20 cap screw will be put through the center hole. This screw will center the engine in the rocket body. The other two holes will be used to fill the top of the cap with hydraulic cement.



INSTRUCTIONS 10

Using a 5/32" hex bit or 5/32" hex key, thread a 1/4-20 x 1" cap screw through the center hole on the cap. Install the screw from the inside of the cap out.

WHY? Don't over-tighten the 1/4-20 x 1" cap screw, just screw it in until it's flush with the inside of the cap and snug.



INSTRUCTIONS 11

By this time the engine should have cooled for three hours and the fuel has had time to harden. Hold the engine casing in one hand and using a pair of channel locks, firmly grasp the aluminum coring rod. Twist the channel locks down while holding the engine casing in your other hand. This will break the seal between the fuel and the coring rod.



INSTRUCTIONS 12

Hold the engine casing and coring rod guide firmly in one hand and using a pair of channel locks, pull the coring rod out of the engine. Pulling out the coring rod may take a little muscle at first but once the coring rod starts to come out, it should slide out very easily.





INSTRUCTIONS 13

lay the coring rod, the coring rod guide and the channel locks down on the table.
At some point, spray a little WD-40 on the coring rod and wipe it off with a paper towel. This will remove any fuel residue on the coring rod and keep it clean until the next time you use it.



INSTRUCTIONS 14

Using a pair of needle nose pliers, remove the small piece of paper in the nozzle throat.



WHY? There will be a small circle of paper with a little fuel on it where the coring rod pierced the paper disc.



INSTRUCTIONS 15

Using an electric miter saw, cut the engine casing at the 31 3/4" mark made in chapter 9, step #57.



OPTIONS A pipe cutter or hacksaw can be used in place of an electric miter saw.

WHY? The engine needs to be an exact length in order for the threaded inserts on the side of the nozzle to line up perfectly with the holes on the lower rocket body section.



INSTRUCTIONS 16

Look down the core in the fuel. It should be smooth and free from any cracks or holes. If there are any cracks, holes or voids, soak the engine in water to dissolve the fuel and start over with a fresh nozzle and engine casing. Most likely the fuel core will look beautiful, like this.



WHY? Holes, cracks or voids will increase the surface area when the engine burns. This will increase the chamber pressure and most likely cause the engine to explode.



INSTRUCTIONS 17

Using a flat screwdriver, remove any excess fuel on the top of the engine casing. The fuel will just peel off the sides of the PVC.
Once the excess pieces have been removed, soak them in water to dissolve them. DO NOT throw them in the trash.



WHY? If left in place, the scraps of fuel on the sides of the PVC pipe will burn faster than the smoke element and cause the casing to overheat.



INSTRUCTIONS 18

If the top of the fuel in the engine casing isn't flat, take a flat screwdriver and scrape away any fuel necessary to make it flat.



WHY? The igniter needs a flat surface to sit against.



INSTRUCTIONS 19

Slip the drilled out coupling from step #5 on to the engine casing.

WHY? The coupling will be installed over the engine casing where the smoke element is. The smoke element has a tendency to burn through the engine casing and this coupling prevents that.



INSTRUCTIONS 20

Push a vinyl plug into the nozzle throat. Push it into the throat until it seals against the steel washer. If you push it in too far and it goes into the core, just pull it out with a pair of needle nose pliers and try again.

OPTIONS There are many plugs on the market that will do a good job but the price of these plugs is so low and the job they do is so good it's not worth the effort.

WHY? The vinyl plug forms an airtight seal in the nozzle throat. This will prevent the potassium nitrate from absorbing moisture from the air and increase the shelf life of the engine.

WHY? Whatever you use to plug the nozzle, make sure it comes out easily. If you plug the nozzle with a plug that is hard to get out, the engine will explode when lit.



INSTRUCTIONS 21

Center the igniter made in chapter 10 on the top of the fuel. Press it down firmly with two fingers until it pushes into the fuel just a little bit.

WHY? When the igniter is lit, the flames will travel down the core of the engine and ignite all the fuel along the core at once.

WHY? Pressing the igniter down into the fuel just a little bit will seal the igniter to the top of the fuel. This way when epoxy is poured in on top of the igniter, it won't drip down the core.



INSTRUCTIONS 22

Put two pumps of epoxy resin and two pumps of hardener into a plastic cup.

OPTIONS Any two part epoxy will work well for the smoke element. *West Systems* is expensive but works very well. Some experimentation with other brands may yield a cost savings.

WHY? *West Systems* epoxies come with calibrated pumps that pump the correct ratio of resin and hardener each time. Two pumps of resin and hardener is almost equal to two ounces.



INSTRUCTIONS 23

Use a disposable wooden skewer to mix the epoxy resin and hardener throughly together.

OPTIONS Any two part epoxy will work well for the smoke element. *West Systems* is expensive but works very well. Some experimentation with other brands may yield a cost savings.

WHY? The epoxy will be mixed with potassium nitrate and used as the fuel for the smoke element. Epoxy, by its very nature has a strong molecular bond, so it will burn slowly.



INSTRUCTIONS 24

Take the metal pan from the toaster oven with the remaining potassium nitrate in it and put it through a coffee grinder. Set the coffee grinder on its finest setting.

WHY? The potassium nitrate needs to be ground to a very fine powder to work well as an oxidizer with the epoxy.



INSTRUCTIONS 25

Measure out 0.19 pounds potassium nitrate into a plastic cup.

WHY? 0.19 pounds potassium nitrate makes up 65% of the potassium nitrate / epoxy mixture. If you are using an epoxy other than *West Systems* with the pre-calibrated pumps, you will need to calculate the correct amount of potassium nitrate to reach a 65/35 ratio.



INSTRUCTIONS 26

Throughly mix the potassium nitrate and epoxy in a plastic cup. The mixture will be thick but pourable.



INSTRUCTIONS 27

Pour the epoxy into the top of the engine casing over the igniter. Pour it slowly so the epoxy has a chance to flow between the sides of the igniter and the engine casing.





INSTRUCTIONS 28

Let the epoxy harden for two hours.



WHY? The fuel in the engine is now completely sealed and as long as it remains like that, the engine will have a shelf life of six months or more.



INSTRUCTIONS 29

After the epoxy has had a chance to harden, use a small piece of scotch tape and tape the ends of the igniter wires together.

MATERIALS Scotch tape.

WHY? Taping the ends of the igniter wires will make it easier to fit the wires through the hole in the cap.

WHY? The next few steps need to be completed quickly and in sequence. Make sure you read the next few pages before you proceed.



INSTRUCTIONS 30

Coat the inside of the cap from step #10 with PVC glue.



MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 31

Lay the engine on its side and apply PVC glue to the top of the engine casing. Immediately proceed to the next step.

WHY? When the engine is burning, there will be a lot of pressure against the cap. It's better to apply glue to both the pipe and the cap to ensure a tight bond.

MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.



INSTRUCTIONS 32

Thread the igniter wires through either of the two open holes on the cap. Attach the cap to the engine casing. Immediately proceed to the next step.



INSTRUCTIONS 33

Apply a little more PVC glue around the engine casing under the cap. Immediately proceed to the next step.

MATERIALS I use *Christy's Red Hot PVC Glue* which does not require a primer but any PVC glue will work.

WHY? The glue here isn't really to seal anything, only to hold the coupling in place on the engine casing.



INSTRUCTIONS 34

Slide up the coupling against the PVC cap and give it a twist. Wipe off any excess glue.

WHY? The smoke element has a tendency to burn through the engine casing and this coupling prevents that.



INSTRUCTIONS 35

Purchase the following part:
• *Rocktite* hydraulic anchoring cement.

Measure out 1 1/2 level cups of hydraulic anchoring cement into a *Ziploc* bag. Add 1/2 cup clean water to the hydraulic cement. Close the *Ziploc* bag and mix the cement by kneading the bag until the cement mixture is smooth.

MATERIALS Rocktite hyaraulic anchoring cement 5 lb. box.

OPTIONS Any type of hydraulic cement should work. Just make sure the cement EXPANDS as it dries otherwise the cement will not form a tight seal against the cap.

WEB www.mcmaster.com part number 7569T92.



INSTRUCTIONS 36

Once the cement mixture is smooth, cut a corner off the *Ziploc* bag and pur the mixture into a plastic cup.



INSTRUCTIONS 37

Fill a plastic syringe with the hydraulic cement. The plastic syringe is OPTIONAL. The cement can be poured directly from the *Ziploc* bag.

MATERIALS 50cc Plastic syringe.

OPTIONS Using a plastic syringe is convenient but not necessary. Pouring the cement directly from the *Ziploc* bag might be a little messy but will get the job done.

WEB www.mcmaster.com part number 7510A665.



INSTRUCTIONS 38

Add hydraulic cement to the top of the engine.

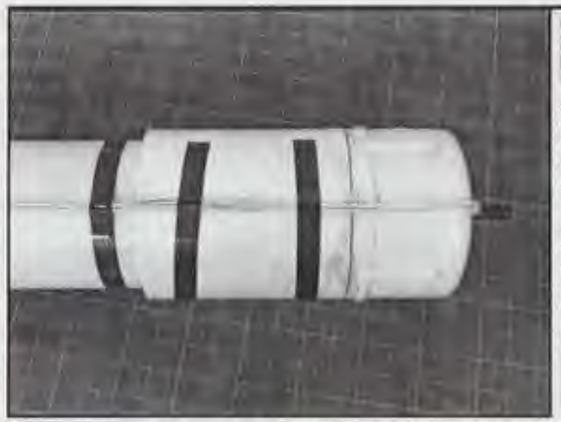
WHY? Usually there is a little space between the smoke element and the cap. In order to prevent the smoke element from being pushed up by the chamber pressure, hydraulic cement is added to fill the gap.



INSTRUCTIONS 39

Once the hydraulic cement starts to flow out the second 7/32" hole, stop injecting cement and wipe off any excess from the top of the cap. Let the hydraulic cement harden for about 30 minutes.





INSTRUCTIONS 40

Starting at the cap, lay the igniter wires down along the side of the engine and tape them in place with packing tape every three to four inches. Run the wires down the engine in line with one of the four screws on the nozzle. This will prevent the wires from getting snagged on the screws from the fins when the engine is installed in the rocket body.



MATERIALS

Masking tape or packing tape.

WHY?

Keeping the ignition wires tight against the engine will make it easier to install and remove the engine and will prevent the wires from getting snagged or damaged.



INSTRUCTIONS 41

Continue to tape the wires on the side of the engine casing all the way down to the nozzle.





INSTRUCTIONS 42

At the nozzle end of the engine, zip tie the remaining igniter wires and tuck them into the nozzle for safe keeping. Keep the completed engine stored on its side to relieve any stress on the fuel grain.

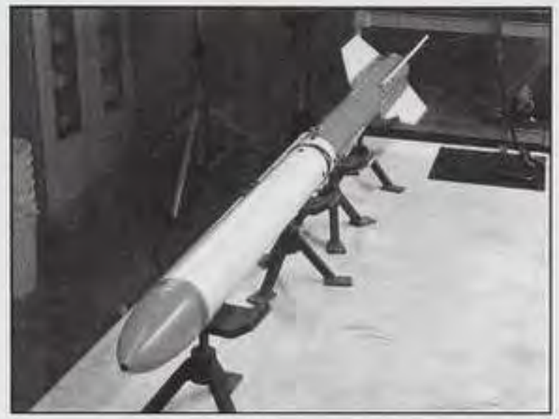


MATERIALS

Small zip tie.

WEB

www.mcmaster.com part number 7130K52.



CHAPTER 13

ASSEMBLING THE UPPER AND LOWER BODY SECTIONS

In this chapter the whole rocket comes together. The engine is installed in the lower body section and the lower and upper body sections are connected. One of the strengths of this rocket design is how easily all the parts are connected.



INSTRUCTIONS 01

Purchase the following parts:
- Two 1/4" x 1 1/4" Steel fender washers.
- Two 1/4" x 1/2" x 3/8" Nylon spacers.
- Four 1/4" x 1/2" x 1/8" Nylon spacers.

MATERIALS
Two 1/4" x 1 1/4" Steel fender washers.
Two 1/4" x 1/2" x 3/8" Nylon spacers.
Four 1/4" x 1/2" x 1/8" Nylon spacers.

WHY?
The 3/8" spacers and the fender washers will be used to guide the rocket up the launch rail and the 1/8" spacers will ensure the engine is sitting in the center of the rocket body.

WEB
www.mcmaster.com part number 91255A543.
www.mcmaster.com part number 94639A570.
www.mcmaster.com part number 94639A567.



INSTRUCTIONS 02

Purchase the following parts:
- Four 1/4-20 x 5/8" button head hex screws.
- Two 1/4-20 x 1" button head hex screws.

MATERIALS
Four 1/4-20 x 5/8" button head hex screws.
Two 1/4-20 x 1" button head hex screws.

OPTIONS
Any type of 1/4-20 x 5/8" screws can be used but I like the button head hex screws because the screw heads are more aerodynamic. I realize it really doesn't make any difference in the performance of the rocket, I just think they make the rocket look sleeker.

WEB
www.mcmaster.com part number 91255A539.
www.mcmaster.com part number 91255A542.



INSTRUCTIONS 03

Put the lower body section from chapter 2, the upper body section from chapter 8 and the completed engine from chapter 12 on a table.

OPTIONS Many adjustable stands are available online. Having a few of these handy makes it easy to work on the rocket sections without them rolling around.



INSTRUCTIONS 04

Using a 5/32" hex key, remove the four 1/4-20 x 5/8" cap screws from the nozzle. Leave the screws on your work surface.

WHY? These screws will hold the rocket in place in the lower body section.



INSTRUCTIONS 05

Put the lower body section on the floor and lower the engine into it. Try to line up the threaded inserts on the nozzle with the 17/64" holes between the fins. Lower the engine half way and then pick up the lower body section, turn it on its side and gently push the engine the rest of the way in. Don't drop the engine into the lower body section.

WHY? There's a plastic ring around the end cap that's just a little to wide to allow the engine to go into the lower body section through the fin end. This ring can be sanded off before adding the cap to the engine. On some brands of PVC caps, the ring is not even there.



INSTRUCTIONS 06

Put the lower body section on a table. Make sure the 1/4-20 x 1" cap screw on the top of the engine is sticking out the top of the lower body section.

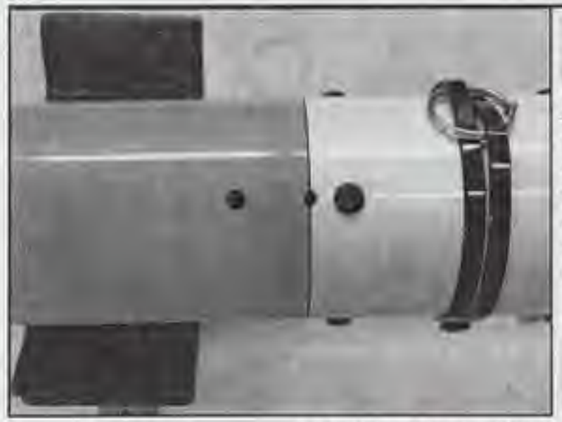
OPTIONS Many adjustable stands are available online. Having a few of these handy makes it easy to work on the rocket sections without them rolling around.



INSTRUCTIONS 07

Line up the lower body section and the upper body sections.

WHY? The 1/4-20 x 1" cap screw on the top of the engine goes into the 1/4" hole on the bottom of the apogee detector. This prevents the engine from moving horizontally during flight. The cap screw sits snugly in the 1/4" hole, there are no threads.



INSTRUCTIONS 08

Slip the 1/4-20 x 1" cap screw on the top of the engine into the 1/4" hole on the bottom of the apogee detector. Push the bottom of the apogee detector into the lower body section. Make sure the notches showing the center line from chapter 1 on the lower body section and upper body section line up. This will ensure that the two pieces of pipe fit squarely together.

WHY? Having a center line that all the templates relate to is the easiest way to make sure everything lines up and fits correctly on the rocket body.



INSTRUCTIONS 09

Using a 5/32" hex key, put three 1/4-20 x 5/8" cap screws into the threaded inserts on three of the four holes in the lower body section. Leave the threaded insert near the notch empty as this is where the rail guide will go.
Don't tighten the screws all the way, leave them a little loose for now.

OPTIONS Any type of 1/4-20 x 5/8" screws can be used but I like the button head hex screws because the screw heads are more aerodynamic. I realize it really doesn't make any difference in the performance of the rocket, I just think they make the rocket look sleeker.



INSTRUCTIONS 10

Assemble the rail guide by putting a 1/4-20 x 1" cap screw through a 1/4" x 1 1/4" fender washer. Then put a 1/4" x 1/2" x 3/8" nylon spacer on the cap screw. See the picture for clarification.

OPTIONS Many commercial rail guides are available. This design works with the rocket and is very inexpensive.

WHY? A 1 5/8" strut channel will be used as the guide rail when the rocket is launched. Two rail guides like the one above will keep the rocket close to the rail.

WHY? The guide rail allows the rocket to gain speed and aerodynamic stability before it's released to fly on its own.



INSTRUCTIONS 11

Put the rail guide into the last threaded insert on the lower body section center line.
Tighten all four cap screws that hold the two section together. It's not necessary to over-tighten the screws, just hand tighten them.





INSTRUCTIONS 12

Put a 1/4" x 1/2" x 1/8" nylon spacer on the inside of the rocket body near the nozzle of the engine.



OPTIONS Many adjustable stands are available online. Having a few of these handy makes it easy to work on the rocket sections without them rolling around.



INSTRUCTIONS 13

Lift up the engine by pulling the nozzle up gently with your thumb and forefinger. Use a small flat screwdriver to push the nylon spacer back under the nozzle, between the threaded insert on the nozzle and the 17/64" hole on the rocket body.



WHY? The nylon spacer is used as a guide to make sure the engine is sitting in the center of the rocket body.



INSTRUCTIONS 14

Put a 1/4-20 x 5/8" cap screw up through the 17/64" hole on the bottom of the rocket body, through the 1/8" nylon spacer and into the threaded insert on the nozzle. Don't tighten the screw all the way, leave it a little loose for now.



WHY? Having four 1/8" nylon spacers around the engine, between the engine and the rocket body will center the engine in the rocket body.



INSTRUCTIONS 15

Repeat step #12 through #14 with three of the four holes on the rocket body. Leave the hole on the center line empty for the second rail guide.

WHY? Two rail guides are necessary to keep the rocket straight on the guide rail.



INSTRUCTIONS 16

Repeat step 10 and assemble another rail guide. Thread the rail guide into the last hole on the rocket body near the center line. Thread the rail guide up through the 17/64" hole, through the 1/8" nylon spacer and into the threaded insert in the nozzle.



INSTRUCTIONS 17

Tighten all four cap screws that hold the engine in place. It's not necessary to over-tighten the screws, just hand tighten them.

WHY? The four nylon spacers will prevent the engine from moving horizontally during flight and will keep it centered for a straight, vertical flight.



INSTRUCTIONS 18

Check to make sure the two rail guides on the side of the rocket line up.



INSTRUCTIONS 19

CONGRATULATIONS! The rocket is now complete and ready to fly. You will find that with each subsequent engine, or even rocket you build, you will become more proficient and the process will become easier.
Make sure to submit photos or video of your project at www.inverseengineering.com so they can be posted on the site or just shoot me an email to let me know how your project turned out.
Thank you for purchasing this book!



I STILL HAVE ALL MY FINGERS

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What's important when building a rocket from scratch? How about high performance, ease of construction and safety. Let's face it; nobody wants to lose a limb. With over fifteen years experience building rockets, Dan Pollino's latest manual makes this seemingly daunting project simple. You'll learn such fundamental tasks as:

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- Making an electromechanical apogee detector
- Making the nozzle with cement and a steel washer
- Making the fuel from ordinary sugar

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Dan Pollino's rockets have been featured on G4 TV's "It's Effin Science." His website www.InverseEngineering.com focuses on amateur rocketry in California.

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